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Budget Planning for Municipally Owned Water Works

By J. P. Schwada

A STUDY of the budget system in this country discloses that a generation ago it was seldom, if ever, discussed outside of academic circles. (See reference 1.) Political leaders were not interested in it; public officials knew little or nothing about it, and citizens were almost entirely ignorant of its possibilities as a device for the control of public funds. As a result there was no comprehensive financial planning covering the income and expenditures of our national, state and local governments. No one could foretell the amount of money which would be spent during a fiscal year or whether the year would close with a surplus or deficit. In many cases, money was borrowed through the issuance of long term bonds to provide funds for payment of current bills, thereby mortgaging future resources to meet operating expenses. A sort of hit and miss policy characterized governmental financial activities of the past generation.

Since that time conditions have changed and real progress in budget procedure has been made in this country. Public officials today, as a rule, appreciate the importance of a real budget, a budget that is based on the experience of the past and on a long range plan for the future so that financial obstacles may be avoided and public business

carried on with some degree of coordination and efficiency. Our citizens too, having recognized the value of a properly prepared budget, now take an active part in its planning, either as individuals or as members of civic organizations. The hit and miss policy of the past has generally been supplanted by a system of orderly financial long range planning—the budget system.

Water Works Constitute Greatest Opportunity for Budgeting

Greater possibilities for such procedure are to be found in the planning of the budget for a municipal water works than in any other phase of municipal endeavor. The municipal water works is one of the most important local industries; it is a going institution which will function as long as the municipality exists. It is also a growing institution that, generally speaking, can and should be self-supporting and self-perpetuating, with rates adequate to support the present service and to provide for the orderly expansion of the system. It is a municipal institution wherein the experiences of the past, if properly interpreted, will aid greatly in planning the future. All these factors make it possible for water works officials and the communities they serve to use the budget as a powerful instrument in the management of the water works.

Developing a Financial Policy

Since it is necessary in the planning of the budget to forecast revenues and expenditures, and since the revenues, and, to some extent, the expenditures also, depend upon the policy followed in operating the water works, consideration will first be given to the question of policy which is brought into the picture by virtue of the fact that the water works considered is municipally and not privately owned. Many municipally owned water utilities are operated on the basis of earning only a nominal rate of return. Some others are operated on the basis of earning sufficient return to permit a steady appropriation of surplus earnings to the general fund, in addition to tax equivalents. Still others, are operated on the principle of obtaining as much money as possible for the general fund to relieve tax payers.

These different objectives are sometimes the cause of controversy between municipal plant officials and city officials and members of the council, but a choice must be made before setting up a budget. Associated with this choice is the determination of policy relative to the method of financing additions to plant. Shall additions be financed out of reservations for depreciation or from surplus earnings

of the plant itself, or shall only nominal additions to plant be so financed, with the major improvements paid for from city funds, raised possibly through bonds issued as a general city obligation or through a mortgage or revenue bond issue against the water works itself?   Such bond issues also present the question whether the water works or the city is to be responsible for the serial payment of the principal of the debt as distinct from the payments of interest itself.

If a city decides to operate its water works on a basis of a nominal return, then a budget which contemplates only small additions and improvements to plant might be set up satisfactorily.   But if a major addition is found to be necessary and the city still wants to operate on a nominal return basis, then provision must be made for obtaining funds from some other source, either by a revenue or mortgage bond issue on the plant itself, or by borrowing from the city general fund.   City officials should recognize that business-like operation of the utility, without demands upon the city general fund for future major improvements, requires that the water works be permitted to operate without making appropriations of surplus earnings to the general fund.   This contemplates that any surplus earnings above operating expense, depreciation, and perhaps taxes, should be left with the water works in the form of an improvement or replacement fund so that improvements required to provide adequate service to consumers need not be deferred for lack of money.   Under such circumstances it might even be necessary for the budget to contemplate deferment of payment of tax equivalent during a given year.

If the water works is operated on the principle of securing a return sufficient to make a regular annual appropriation to the general fund, and city officials are insistent and unwilling to waive this appropriation in the face of needed major improvements, then municipal plant officials might find it advantageous to budget plant additions over a longer period in order to avoid embarrassment from lack of funds when such major improvements become absolutely necessary.   In other words, provision in the budget for additions to plant might have to be distributed over a period in advance of their actual necessity.

Diversion of Water Works Funds Dangerous

In this connection it is emphasized that experience has shown that those cities which operate their water plants on the principle of getting as much money out of them as possible find that sooner or later a

day of reckoning occurs and service tends to become impaired because
funds for improvements are not available. Then too, when large
annual appropriations to the city's general fund are made to reduce
taxes, real estate owners with large property investments often re-
ceive benefits in the form of tax reductions which are in excess of the
annual water bills paid. This is especially true of owners of vacant
real estate who receive such benefits without having contributed to
the revenues of the water utility. On the other hand many large
consumers of water derive little benefit from such appropriations to
the general fund. This procedure is obviously unbusiness-like and
unless carefully considered may unexpectedly upset the preparation
and enforcement of any long range budget.

It might also be pointed out that ordinarily a municipally owned
water works contemplates the retirement of bonded indebtedness as
soon as possible and follows the serial maturity principle. This is a
wholesome principle of finance. But, of course, in preparing a
budget, this policy must be considered and there must be a clear
understanding with city officials, whether the water utility or the
tax payers are to be held responsible for meeting serial repayments of
principal.

Under most circumstances, not only from the standpoint of setting
up a budget but also from the standpoint of fairness to the con-
sumers, as well as for the many advantages to be obtained, a mu-
nicipally owned water works should be self-sufficient and self-sustain-
ing. It should not be dependent upon appropriations from general
funds to finance plant additions. Instead the budget should con-
template that the water works retain most, if not all, surplus earnings,
especially if it is earning only a nominal return, thus establishing an
improvement and replacement fund by equalized payments over a
period of years to provide the necessary funds for future additions to
plant. A definite financial policy, however, must be determined
before a budget can be set up.

Long Term Planning

When the financial policy has been decided upon, consideration
should then be given to long term planning which a city should per-
form in order to maintain its water supply property in proper condi-
tion to serve the public adequately. Studies should be made to
anticipate the needs of the service for at least twenty years in ad-
vance so that the water works can be built and maintained according

to a definite program.   Such a program should be predicated upon population growth and water consumption rather than upon time as the only element, and should consider also the direction of growth in the community.   It should be reviewed at intervals of approximately five years and comprehensively adjusted to fit the matured conditions at intervals not in excess of ten years.

It is practicable, as has been pointed out by Howson (2), "to forecast the future water requirements of a water works, study the various practicable methods of meeting them and develop a comprehensive plan for progressive enlargement of the various parts of the water works, such as the pumping and purification facilities, distribution system, feeder mains, etc.   The approximate order of construction of each step can be determined, the cost estimated, and the total expenditures so distributed as to effect a relatively uniform demand for funds."

The budget should include allowances for engineering services to prepare a long term plan and to review it periodically.   If this is not done, a community may, as has happened time and again, find itself with an inadequate water supply and be forced to curtail consumption.   Pumping facilities should be planned and constructed well ahead of time because too often the construction of them involves more time than allowed.   The same applies to purification facilities.

So far as the distribution system is concerned, the budget should provide for recording instruments to obtain data so that the system can be properly extended and changes made where necessary.   In the past the design of water works distribution systems has too often been based on rule-of-thumb methods which today are outmoded and should be replaced by scientific methods.   Recording instruments should be placed in the distribution system or at least on the trunk mains of the system to indicate the rate and direction of flow and pressures at all times and especially during periods of peak demand.   With such information, systems can be extended in a scientific and economical manner as a part of a long term·program. A small investment made each year will accomplish much toward this end, and the budget should provide for it.

In a growing community land is annexed periodically and water mains, including feeder mains, must be installed.   A long term program reviewed periodically is advantageous because it will consider the trend of expansion and serve to guide future extensions. Necessary additions can be planned more rationally and extended to

the consumers a little in advance of need and without undue cost, and as the growth justifies the outlay, instead of wasting many thousands of dollars.

There are other advantages to be obtained from a budget based on a long term program. For instance, under such an arrangement, projects can be planned more deliberately and with sufficient time for adequate study of the facts involved and the relative merits of alternative schemes. Preliminary layouts can be made for future projects and held in readiness for use at opportune times. In addition, sites can frequently be acquired at low cost ahead of the actual construction of a project.

Then too, a better qualified and permanent engineering organization can be maintained to plan and construct new work. This whole procedure is certain to produce better results at less cost than hurriedly conceived projects often resorted to when popular enthusiasm instead of judgment carries the day.

Setting up the Budget Proper

When the financial policy has been decided upon and a long term program made, the next step, of course, is to set up the budget proper. This is best done by considering the budget in two parts: part one which is the annual budget and deals with the operating expenditures and operating revenues, and part two which has to do with capital expenditures and means of providing finances for such capital expenditures. This setting up of the budget proper will not be discussed in detail here because the principles to be followed and the forms used are already well established.

It is suggested that each utility keep a ledger recording the distribution of the expenditures according to the budget classifications. This will enable the budget to be made out much more accurately because experiences of different years will be available for comparison. It is further suggested that each division head in a municipally owned water works keep a record of the items that should be included in the following year's budget so that they will not be forgotten when the budget is prepared.

While the budget for any fiscal year is a statement of the revenues and expenditures, it should be set up and considered as a part of a budget or program planned for a definite number of years in the future. Such a program should display each project of construction and maintenance in terms of estimated costs, allocating priorities to improvements in the order of their urgency. The program should

also suggest the means by which funds are to be secured.   Thus, while projects selected for the current year are definite, the improvements allocated to specific years in the future are open to revision once each year while the new budget is made.   In this manner will the long term program accomplish its real purpose.

Another problem that confronts many a water works manager in the preparation of a budget is that of getting a fair share of the expendable funds in the community so that the property can at all times be kept in proper condition to serve the public and extended to meet the growth of the community.   This is quite often a difficult task because of the lack of appreciation of the importance of the water works on the part of the public officials in control of the situation, and because it may be expedient to use water funds for other municipal enterprises or to reduce taxes.   Quite often the task is made more difficult by private organizations which are more concerned with their own financial interests than with the health and comfort of the average citizen to whom the water works is of paramount importance.

What can be done so that the water department will get its fair share of the expendable funds?   What steps should a water works manager take to obtain sufficient funds to maintain the water works in proper condition and to make needed improvements and extensions?   Of course, there is a limit to what any good manager can do when the financial control of the water works is in the hands of persons who insist on using water department funds for other purposes, either for political expediency or because they sincerely believe it good business to do so.   An effort should be made, however, to retain in the treasury of the water department all surplus earnings above operating expense, depreciation, and taxes so that service can be maintained and improvements made when needed.

Today in many communities real estate organizations and owners of large properties are urging tax limitation on real estate on the grounds that real estate is bearing too large a share of the general taxes in proportion to the services rendered.   It is claimed that sound business principles and equitable treatment require the shifting of taxes.   And yet, these same interests are often most active in promoting the transfer of water department surpluses to the general fund in order to reduce taxes.   These same interests, too, are active in certain instances in bringing pressure to bear upon officials to delay or postpone improvements needed in the water works.

There is no sound reason why the water works should be a source

of revenue for the operation of other public enterprises. If the revenues of a water department are greater than required for its operation, maintenance and construction, then the rates should be lowered and the benefit given to the consumers. This policy should be advocated by the water works manager and placed before the public so that its support may be gained when the budget is set up. If individuals and private organizations bring pressure upon officials to transfer funds from the water department, then the management is certainly privileged to seek the support of the public in the carrying out of a policy that is fair and businesslike. If the management of the water works will inform the public that a well defined program has been laid out and must be adhered to or a day of reckoning will come, and that service may be impaired if sufficient funds are not available, the management can surely accomplish more than through attempts to carry out a policy alone. The public can and will appreciate the importance of the water works if it is educated to that point of view.

It has already been mentioned that in many communities organizations are urging tax limitation on real estate. In many communities it has been done. Why, then, cannot some legal limitation be placed upon the transfer of surplus revenues from a municipally owned water plant to a city's general fund? Why, then, cannot legislative bodies adopt or establish a definite policy governing the transfer of surplus revenues? A good water works is a necessity and all possible protection should be given it. If that is done, a real budget, based on a long term plan, can be carried out. One thing is fundamental if success is to be achieved—the financial phase of the program must be planned and executed with the same care and integrity that is given to the engineering details. Only by such an approach can the municipally owned water works maintain its rightful place in the community it serves and give the water consuming public what it wants—which is good service. When that is done, the budget for the water works can properly be planned.

References

(1) BUCK, A. E. *Public Budgeting*. Harpers, New York (1929).
(2) HOWSON, L. R. Water Rates and Construction Policies in Municipally Owned Plants. Jour. A. W. W. A., **25**: 79 (1933).

Planning Water Works Property Development

By C. J. Alfke

IN ORDER to develop a property devoted to any business, the development must necessarily be guided by the maximum capacity the property is to attain and the time in which such maximum capacity is to be attained. In industry, management can determine the maximum capacity to which it desires to develop a property and stop. In developing a water works property, be it operated either by a governmental division or commission, or privately, management must be guided by the future consumption of its product in the territory it serves and must look ahead a number of years, let us say about ten, and then look into the longer future. With the complete statistics relative to population growth and trends which are now available and with a knowledge of current conditions, it is, in my opinion, possible to make a fairly accurate prognostication of population growth for ten years in most territories and, by adjusting estimates with experience, a long term estimate of future consumption can be maintained which will be of considerable value. Therefore, the phase of planning the development of a water works property which I intend to cover will be confined to that which can be described as the determination of the trend of future consumption.

Tabulating figures of past experience, both consumption and population in the territory served, by years, or making a graph of them, will give the starting point for a prognostication of future consumption. It is not advisable to prolong the past experience line along its trend to get the probable future experience line. It does not work out. Past experience must be tempered with knowledge of prevailing conditions and trends affecting future population growth. Once the determination is made, plotted and annually adjusted, the ex-

pansion of the property becomes a matter of engineering, viz.,
developing the plant to serve adequately and safely the demand which
is being made upon it and which it is expected will be made upon it
in the reasonably near future, say about 10 years. To prolong the
experience line into the long future, say 40 or 50 years, let us reflect
a bit on what has been happening over a period of years in the
United States to affect consumption of water and population growth.

Consumption Increased by Changes in Plumbing

Since the turn of the century the following changes in plumbing,
heating and sanitation systems in homes and buildings have con-
siderably increased the consumption of water:

(1) The inside diameter of water piping and the inside diameter
as well as the number of outlets in houses has increased considerably.

(2) There has been a substantial increase in the number of homes
equipped with bathrooms.

(3) The trend in the manner of heating has changed from stoves
or ranges in rooms to hot water heating systems and steam heating
systems. Automatic heating systems have come into common use.
Unlimited supplies of hot water are now available, materially in-
creasing water consumption.

(4) Water companies in general have adopted the use of $\frac{3}{4}$-inch
pipe between the main and the curb instead of $\frac{1}{2}$-inch as heretofore.

No statistics are available as to the number of houses in various
parts of the country that are now equipped with modern plumbing,
heating and sanitation systems. Just how far the changes from the
old plumbing systems with fixtures that gave very little water to the
new plumbing systems with fixtures that give plenty of water have
been made I do not know. The increase in the inside diameter of
interior piping and fixtures has accounted for a considerable increase
in the use of water. The majority of home seekers insist upon up-to-
date plumbing, heating and sanitation system facilities. All of the
foregoing still holds true. However, in Northern New Jersey there
have recently appeared real estate developments of small-sized houses
equipped with small-sized inside piping, not $\frac{3}{4}$-inch inside diameter
but $\frac{1}{2}$-inch and sometimes $\frac{3}{8}$-inch. The average family of today
(being considerably less in number than that of years gone by) can
be properly housed in a small-sized house. The trend is definitely
away from large houses to small houses. Smaller houses are also
the result of a decreasing use of the home as an amusement and

recreation center as compared with former years.   My own feeling
is that the increased consumption caused by the stated improvements
is about at an end.

Consumption Affected by Population Growth

There is another factor that has materially affected the increase
in consumption and that is the population increase.   The population
increase in the United States by decades has been very rapid.   There
is a report from the National Resources Committee dated May,
1938 to the President of the United States, the title of which is
"The Problems of a Changing Population."   This report thoroughly
covers the subject of population growth in the United States since
its colonization and prognosticates the future population growth.

The report is the result of an exhaustive study and makes the
following statements relative to our population trends:

"It is apparent that great changes are taking place in the popula-
tion of the United States: transition from an era of rapid growth to
a period of stationary or decreasing numbers, increase in the propor-
tion of children surviving to maturity, limitation of births in varying
degrees among different groups, redistribution of people in relation
to natural resources and social institutions.   Some of these are the
culmination of tendencies that have long been at work.   They affect
the foundations of human experience in biological inheritance, family
relations, and the conditions of daily living.

"Crude rates of natural increase now register the slowing down of
population growth in the United States, and more refined analysis
yields even more striking results.   The birth rate has been declining
for many decades; the total number of births per year reached a peak
in the years 1921-25.   Since 1929 there has been a general trend
toward decrease in the number of births each year.   Moreover, when
"true rates" are computed to eliminate the temporary effects of
variations in age distribution, it is found that the intrinsic repro-
ductive trend is already slightly below that required for permanent
population replacement.   In other words, if no change occurred in
the proportions of persons surviving from birth to different ages or
in fertility rates of women at different ages, population growth would
gradually cease.   Actually there is good reason to expect that further
decline in fertility rates will be more rapid than the rise in survival
rates.   Furthermore, there will be a peak in the number of young
persons of marriageable age about 1945 (about 20 years after the

peak in the number of births already mentioned).   Therefore, after
the middle of the century further decrease must be expected in the
number of births each year unless present trends in fertility are
reversed or unless the population is augmented by heavy immigration.

Up-to-date Estimates of Population Changes

"The most recent estimates of future population change, prepared
for this report by Warren S. Thompson and P. K. Whelpton, are
based on three sets of hypotheses for birth rates and for death rates.
On the assumption of medium fertility and mortality rates, popula-
tion will continue to grow for 50 years but at a constantly decreasing
rate, reaching *153,000,000* in 1980.   Assuming a net immigration
of 100,000 persons per year from 1940 on, the figure for 1980 is raised
to *158,000,000*.   Even with the highest rates that can reasonably
be assumed, there would be a natural increase of less than 50,000,000
from 1935 to 1980.   The minimum estimate assumes a decline of
about one-third in the fertility of native white women from the
1930-34 level to 1980, with no net accession of immigrants.   This
estimate gives a peak population of *138,000,000* in 1955 with a de-
crease of 10,000,000 during the next quarter century.

"A change in age distribution is accompanying the change in trend
of total population.   The estimates for 40 years hence, based on
'medium' assumptions as regards births and deaths and with no
allowance for immigration, indicate the presence of an approximately
equal number of persons—about 2 million—at each year of age from
birth to 60 years.   There will be a smaller number of persons at the
later ages, but they will form a much larger proportion of the total
than at present. In 1900 there were 90 persons under 20 years of age
for each 100 persons aged 20 to 60 years, whereas the corresponding
ratio in 1935 was only 68 and by 1975 will be about 48.   Conversely,
where there were 13 persons over 60 years of age per 100 persons
aged 20 to 60 years in 1900, the corresponding ratio in 1935 was 17
and in 1975 will be about 34.

"These changes present a whole new set of national problems, the
problems of a 'mature population.'   This characterization of the
situation in Minnesota by the planning board of that State is appli-
cable to the Nation as a whole:

   'Minnesota has come of age and is reaching a period of
   maturity. . . .   This is in no sense a cause for gloom.
   The period of middle age may be for a nation as for an in-

dividual, the most productive and happiest period of exist-
ence.   We are, however, face to face with the sober and
thought-provoking necessity of developing a way of life for
a mature community.'

"The urban population of the Nation is already so great in relation
to the rural population that future growth of cities will be much
slower and more uncertain than in the past.   Urban growth will
probably expand the periphery of existing industrial and commercial
centers faster than the central cities.   The population of the nation
appears to be approaching stabilization both in number and in geo-
graphical distribution.

"Due to the rapidity with which the original population of the
United States has increased, it is not commonly realized that the
birth rate has been declining for nearly a century.   Until recently
its effects have been counterbalanced by a decided decrease in mor-
tality rates, by heavy immigration of adults, and by the fact that
there has been a large proportion of the females in the childbearing
ages.   It is evident, however, that since the mortality rate cannot
decline indefinitely, and since immigration is now drastically re-
stricted, the decline in the birth rate must soon outweigh the factors
tending to increase the population and bring about a decline in an-
nual increments of population growth.   In fact this turning point was
reached about 1925.   In the early twenties (1920–24) about 1,880,000
persons were being added to the population each year.   Ten years
later (1930–34) the increase averaged less than half as many—about
900,000 persons per year.   Part of this spectacular change in the
rate of increase was due to the decline in net immigration from about
400,000 per year to a net emigration of nearly 60,000 per year; but
the major factor has been the decrease in the excess of births over
deaths."

Four Factors in Population Change

There are four factors that affect the increase or decrease in pop-
ulation, birth rate, death rate, immigration and emigration.   All
of these factors are declining but the death rate is declining at a
much less rate than the others and the decline in this factor will not
go much further, but as the average age of the population increases
the death rate will increase again.

Overcrowding is ceasing in the elementary schools.   Empty desks
and reduced teaching staffs are reported in Cleveland, Ohio.   The

United States Bureau of Education estimates a peak high school enrollment of 6,135,000 in 1938–39, then a recession as the wave rolls on through the colleges. This wave is being caused by the large number of children born immediately after the war and the sharply declining birth rates that set in after 1925.

Population Redistribution

The report of the National Resources Committee makes the following statements (among others) relative to population distribution and redistribution:

"People have entered the United States (1) by various routes as colonists or immigrants and (2) by birth. The first of these primary forces influencing the distribution of population in this country brought people to points along the whole Atlantic seaboard at first, and then lead to concentration of immigrants in certain areas of expanding industrial opportunity, notably in the Northeast, with areas of secondary concentration in other sections, in the Middle States, Northwest, Far West, and Southwest. The second of the primary forces in population distribution (differential natural increase among regions and types of community) has tended toward accumulation of population in the most rural sections of the country. Immigration is now relatively unimportant, but differential natural increase is still an active force. During the years 1930–34, 55 per cent of the total natural increase occurred in the states of the South and Northwest, which contain only about one-third of the total population.

"Internal migration constantly modifies the accumulation of population that would otherwise result in certain areas from immigration or differential natural increase. In many cases it brings about new concentrations of population in response to economic opportunities or other attractions. In 1930, about 23 per cent of the total native white population and 25 per cent of the total Negro population were living outside the States in which they were born. There has been a constant interchange of population between different areas, but two main movements have predominated: (1) the movement to new lands, mines, and jobs in the West—across the Alleghenies into the Ohio and Mississippi valleys, the prairies, the Pacific coast, and finally to dry-farming areas in the Great Plains; (2) the movement to industrial and commercial opportunities in various parts of the country but most notably in the Middle Atlantic, southern New England,

Great Lakes and Pacific areas.   The second type of movement drew people from the very areas previously regarded as areas of new opportunity.   Thus, in 1930, 5,000,000 persons born east of the Mississippi were living west of that river; but the states in the northeast quadrant contained more than 1,650,000 people born west of the Mississippi River, as well as more than 3,000,000 born south of the Mason-Dixon line."

If the total population ceases to grow, population redistribution becomes important.   Americans are becoming increasingly mobile. The main reason for this mobility is the search for greater economic opportunity or security and cultural advancement.   The population moved west from the date of the first settlement along the Atlantic seaboard.   By 1930 it was evident that the general pattern of migration in the country had changed.   The movement of population westward from the Atlantic seaboard had given way to a general movement from the interior to the states of the Pacific coast, the Great Lakes, and the North Atlantic sea coast.   The economic depression changed the pattern of internal migration again in the United States for a time, 1930 to 1935, and a movement started back to the farms.   The actual movement to the farms was never large.   This was to be expected as economic conditions in rural districts were no better than in the cities.

Conclusions

Conclusions which may be drawn are:

(1) Unless there are radical reversals in the downward trend of birth rates and immigration rates, the population of the United States should see its peak within about 15 years, and if present birth rates, death rates, immigration and emigration rates are maintained the peak population should be about 140,000,000.   In years gone by prognosticators estimated a population in the United States of as much as 300,000,000 people by 1980.   These estimates as pointed out previously have been sharply reduced, viz., to as low a figure as 138,000,000.   I am not attempting to make any prognostication of the ultimate total population of the United States, but the trend of increase in population is definitely downward.   The figures in the report of the National Resources Committee indicate that unless the trend is turned, we are fast approaching a point where the population will start to decrease.

(2) Redistribution of population will be governed mainly by movements to areas of economic opportunity and cultural advancement.

(3) The trend of industrial consumption will depend on the trend of business activity. The long trend of business activity will be apt to depend on the future population growth of the country.

(4) By carefully watching population trends in the territory served, it is possible to plan the development of the property operated. Conditions prevailing in particular localities will control the experience of those localities but the probable increase in the total population of the United States will undoubtedly have a considerable bearing on local experiences. There can be little doubt of the advisability of developing a property by stages in order to accomplish the most economical development.

Labor Relations and the Water Works Field

By Leo Wolman

THE subject of labor relations in public utilities and public service is a contentious one. The whole problem of labor relations in any field is contentious in these times when even members of the same family are divided, or at least from time to time think they must be. One must therefore be cautious in what one says.

I should begin by saying that there is no difference in the problem of labor relations in public service and in private employment. In times like these—of great public disturbance; of economic, political, and social crises; when the community is in an experimental frame of mind; when a large part of the population likes to forget the past and write it off—then many of us begin to experiment with an unknown and uncertain future. The experiments that are carried on in one field spill rapidly over into related fields. Consequently one who surveys the developments in labor relations in the United States since 1930, or more particularly since 1933, is struck by the similarity of trend in the areas of public and quasi-public employment in comparison with what has happened in private employment. If we consider the more important developments in the whole field of labor relations since 1933, I think we shall immediately see that they find their counterpart in the manifold divisions of public employment.

Trade unionism among public employees is not a new fact. As a matter of fact, one of the most striking features of the course of American trade unionism is the growth of organized labor among public employees. Even during the period of the 1920's, when the organized labor movement in this country seemed to reach a saturation point and stop its growth, trade unionism among public employees continued to grow and at a rapid rate. This trend was

markedly accelerated after 1933 with the result that both fractions in the American labor movement are today growing rapidly among these types of services. You find large, strong and growing unions in the electrical industry and public services, affiliated either with the C.I.O. or with the A.F.L. Labor organizations in these types of services, so far as one is able to discern, use pretty much the same methods in their negotiations and their efforts to organize and in their efforts to impress their power as they do in private industry and in their relations with private employers. It is not surprising, therefore, to find since 1933 a record of numerous strikes directed against essential public services in the United States. Remember the big, violent street car strike in Milwaukee a few years ago, the shut down of electrical plants in the State of Michigan as an after-math of the sitdown strikes in the automobile industry in 1937 and the frequent strikes of W.P.A. employees. It is not, also, un-common to read of the picketing of public officials and public build-ings. I remember that when I was a public official, I engaged a student who had graduated from my university, who turned out to be, I thought, a man of no great ability, but unusually belligerent. I left this public post and went elsewhere. Later I read in the newspaper that this person had finally been discharged by General Johnson. After he was fired, both the N.R.A. and the U. S. Depart-ment of Commerce were picketed by an *ad hoc* union of his fellow employees.

The conflict between rival unions is being carried on in public as well as in private employment. The jurisdictional dispute between the two great factions of the American labor movement has penetrated public activity. In Washington there are two unions of public service employees, one affiliated with the A.F.L. and one affiliated with the C.I.O., both using the familiar types of union pressure.

From time to time high public officials enunciate the principle that unions of government employees are not authorized to use the strike. But when it comes to a show-down, when the issues are serious enough, and when there is strong feeling in the rank and file, it is very doubtful in my mind that anybody under present circum-stances will have the courage to prevent the use of the strike. We know from the experience in other countries where there have been strong labor movements, where prohibitions were put upon the activities of public employees, when a crisis has arisen, there have

been extensive general strikes. This was true of the French general strike and of similar strikes in the history of the French labor movement, and was true also of the British general strike of 1926.

While this is by no means a complete record of the use of these normal, ordinary, traditional devices of unionism in public employment, we know enough to make it safe to say that labor relations in public employment are tending in this country to observe much the same trend as in private industry.

Objectives of a Good Labor Relations System

This brings us to the larger question. What are the objectives of a labor relations policy in public as well as in private employment? Difficult as they are to put into practice such objectives can be stated pretty simply. Such simple statements can win the support of almost all groups of people because, after all, the objectives of a sensible and workable system of labor relations in any democratic country are essentially simple, easy to state and commend themselves to reasonable men.

The first objective of a satisfactory system of labor relations is a swift and equitable machinery for the adjustment of grievances. The second objective is good conditions of employment including satisfactory rates of wages. Stated in these terms I doubt if there is any one who would refuse to accept and abide by them. The difficulties arise when you try to put these objectives into effect. We have wrestled with this problem since 1933 and if I can judge of the temper of the times, I should say that we have become increasingly dissatisfied with the work we have done.

That we do regard these objectives as simple and practical measures is indicated in the kind of laws we have written, particularly the most important single law that we have adopted in the U. S. in these last years to deal with the problem of labor relations—the National Labor Relations Act, commonly called the Wagner Act. Without going into the various provisions of this Act you will find a single statement of its purpose and of the purpose of that kind of law in its preamble. This preamble confidently states the proposition that—if employees of all kinds can freely build up a trade union movement, the result will be higher rates of wages in this country, stabilized employment, a drastic reduction in the number of the unemployed, and peace and harmony in our industries.

The Wagner Act, stating these simple, direct objectives of labor

relations, has been in effect since 1935 and it has had a very exciting and interesting history. If we can judge by what we read and hear about it, we may infer that this simple plan has come to meet growing dissatisfaction. The evidences of that are all around us. In Washington, both houses of the Congress have been occupied during the last several months in hearings on the operations of the National Labor Relations Act. While a great part of these hearings has been concerned with the personnel of the Board, attacks on their points of view and their political views, at bottom the real problem that these congressional committees have been investigating is whether this kind of law will produce the results for which it was intended.

Nation's Experience with Wagner Act

Throughout the country there are evidences of similar dissatisfaction. Although the Wagner Act was adopted in 1935, it really became effective only in 1937 when it was declared constitutional by the U. S. Supreme Court. Yet the experience of only two years has been sufficient to arouse widespread opposition to the law and its administration. Already several of the largest states of the union have passed local Acts amending the provisions of the so-called "little Wagner Acts." In Wisconsin, one of the leader states in labor legislation in this country, the legislature has enacted a very drastic law limiting the rights of organized labor, as an expression of the opinion of the citizens of that state about the workings of the federal law. Recently the Governor of Pennsylvania, over the protests of both the A.F.L. and the C.I.O., put his signature on a similar law. On the West Coast laws of this kind were adopted at least one year earlier.

One source of dissatisfaction with the Wagner Act is the feeling that it has failed to bring about a state of peace. So long as the law remains on the statute books in its present form and is interpreted in its present manner, there is ample evidence that we must look forward to greater rather than lesser difficulties in labor relations.

Other evidence of our doubts about this legislation and our present labor policy are manifest in the appointment, last year by the President, of a very distinguished Commission which was charged with studying the systems of labor relations in Sweden and Great Britain. In the lay mind of this country, these two foreign countries have discovered the secret of correct labor relations; have learned how to

apply legislation to this problem; and have plans of collective bargaining which work very well. No one, of course, knows offhand just how these systems work in foreign countries, and that is one reason why the President appointed a commission to study them. The commission's report covered many things. But its most striking conclusion, and the one most favorably received, was that peace in industry and the moderation in policy practiced by employers and unions abroad were due primarily to the long experience with, and the general acceptance of, collective bargaining. If we in this country, therefore, have trouble it may be attributed to our youth and inexperience.

But anyone acquainted with labor relations even in a single industry is struck by their complexity. No simple generalization about them is quite true. When I state the objectives of a sound system of labor relations, they sound simple. One might even ask what use there is for a statement of objectives in such terms. The same thing may be said of the record in Great Britain and Sweden. Conclusions based on a cursory survey, which separates a problem from its setting and history, may well be totally misleading.

Experience in Sweden

In Sweden, for example, it is true that collective bargaining between organized employers and organized employees has been practiced much more extensively, and for a longer time, than in the United States. But this is not the whole story. Not many years ago there was a great battle in the building trades of Sweden. For in the building industry of that country there were problems not unlike the problems we have in our own building trades in the United States. One may describe that problem briefly by saying that building costs got out of line with other things with the result that it became more and more difficult to revive this important industry. In spite of the fact that trade unions in Sweden had full legal recognition, the issue finally came to a showdown and the employers locked out their men for many months. The lockout was settled with a substantial adjustment of building costs. Another fact is equally revealing. In the United States we have moved in a few years from a 50- to a 40-hour week in factories, and from a 48- to a 35-hour week in the coal industry. Thus we took 10 and 13 hours off the work-week, and made proportionate adjustments in wage rates, at a time when, to say the least, American industry was not operating at the peak of

prosperity. In Sweden, a much more strongly organized country with much more extensive recognition of trade unionism, the work week is still 48 hours for most occupations and most industries.

Experience in Great Britain

British experience, likewise, must be interpreted in terms of the forces that have played upon labor relations in that country, if it is not to be woefully misunderstood. The British trade union movement, just as the American, was a relatively small and minority movement before the war. During the war it grew very rapidly and after 1920 it was very powerful with its influence and power extended over a greater area than ever before. The British unions became a force to be reckoned with. But, when a labor movement gets strong suddenly, its policies change no matter who its leaders are and no matter what their training. Sooner or later the leaders become exposed to a new force. The British unions had had a long history of conservatism and moderation. But by 1920 they had risen to a new position of power. They reached the climax of their power in 1926. In that year, British labor engaged in a general strike. They lost the strike, and losing it, suffered a stunning defeat. After 1926, the British labor movement was much weaker and chastened.

Some five years later the organized labor movement of Great Britain suffered an equally decisive and demoralizing defeat. This time the defeat took the form of a split in the Labor Party, the loss of the most distinguished leaders of the party to a coalition government, and the resignation of the Labor Government. Coming so close upon the general strike of 1926, this latest episode could not fail to leave a deep impress on the policies and practices of British unionism. It has become, in consequence, more timid, more careful, and, hence, more moderate, both in Parliament and industry. What it has been doing these last 10 years reflects these factors in the postwar history of the British labor movement. And no interpretation of the peace that reigns in industrial relations in Great Britain is sound which fails to take these facts adequately into account.

One of the aftermaths of the defeat of the British general strike was the passage of a new labor law, the British Trade Disputes and Trade Unions Act of 1927. Aside from the changes it made in the legal position of unions, it contains interesting provisions affecting the status of trade unionism among civil servants. According to

section 5 of this Act of 1927, civil servants in England are prohibited from "being members, delegates or representatives of any organization, of which the primary object is to influence or affect the remuneration and conditions of employment of its members, unless the organization is an organization of which the membership is confined to persons employed by or under the Crown, and is an organization which . . . is in all respects independent of, and not affiliated to, any organization or federation which is not so confined to civil servants . . . that the objects of the organization do not include political objects and that it is not associated directly or indirectly with any political party or organization."

This provision of the law means that British civil servants can join a union of civil servants, but not a union affiliated with organizations including in their membership other than civil servants. In this country such a provision would mean that American civil servants would not be allowed to join a union which had outside members, nor could they belong to unions affiliated with either the A.F.L. or the C.I.O. or with any federation of labor of the same general character.

When therefore we refer to the actual experience, such as I have very briefly outlined, we find (as I suspect one would always find when one studies complex systems of labor relations) that there is much more than appears on the surface. So I believe also that we in the United States, who have ourselves had a long experience with trade unions, if we are to work out a solution of our problems, must rely mainly on our own experience, the peculiarities of which we understand.

Our present difficulties, of course, are numerous and formidable. We shall not be able to see what they are unless we have a very clear view of what our basic problem is. It is actually not one of the amount of collective bargaining in the United States, or of the forms of labor relations. The problem lies deeper.

The fact is that since 1930, and more particularly since 1933, we have developed a new and fundamental labor policy in the United States. It has come upon us from several different directions. It has not been concerned solely with the form of labor relations, but it has had a much deeper purpose. This policy is on its face a relatively simple one. Its objective has been the increase of the purchasing power of the American public. If we examine the economic policies of both the Hoover and Roosevelt administrations, we shall

find that the thread which runs through most of them arises out of this objective.

To accomplish this increase in purchasing power, we have used two methods. One is the raising of wage rates, and the second is public spending. Most of our recent legislation and, one might almost say, all of our recent economic policies, are aimed at lifting wages and expanding public expenditures. Now, when I mention this general objective and the two methods we have employed to achieve it, I am obviously touching one of the most debatable issues of our times, and one of the most difficult to evaluate. It is difficult because it states a problem for which there is no plain solution. No one can prove that a country spends too much or too little. No one can prove that wage rates are too high or too low or just right.

What then do we do when there is no proof? We certainly must deal with the problem. We can't simply dispose of it by sitting back and waiting to see what happens. Nor can we accept the policies currently offered simply because they are simple and plausible and, for these reasons, have gained wide popular support. In fact a wrong policy, strongly supported by public opinion, is the more dangerous because it is the more difficult to reverse or to abandon.

Meeting the Problem

Lacking proof, we can look carefully at the facts, marshall relevant historical evidence, and arrive finally at a practical judgment concerning the policy and whether it is worth its cost. This we can do by first inquiring whether the policy has been wholeheartedly applied, or whether it has lost its force through timid and skeptical administration and has been unsuccessful because it has not received a fair trial. If we state the problem that way, we can obviously bring to bear on it common-sense criteria, which thoughtful people should be capable and willing to examine and assess.

Take, for example, the question of wage rates. Has there really been an extraordinary change in rates during these last years? This certainly is a question which can be accurately stated and answered. And if there has been an extraordinary change in rates of wages, has it been followed by a marked reduction in unemployment and by more stable employment? On both these questions, there is a reliable body of facts.

Let us look first at wage rates. We find that the rate of wages in the United States in 1937 (I take the year 1937 because that was

the year of the peak of the latest rise in business activity in the
United States) stood at its highest level for all times in this country.
This was so in the basic industries of manufacturing, rail transpor-
tation, construction, and soft and hard coal mining—a group of
industries which together account for a large share of the gainfully
occupied population.   These rates of wages, moreover, were nearly
triple the 1914 rates and appreciably higher than in 1920 or 1929,
both boom years in the history of American industry.

The rise since 1933 has been one of the fastest of which we have
any record although the drop from 1929 to 1933 was not, as many
believe, excessive in view of the decline in prices during that period.
As a matter of fact, the drop in the rate of wages from 1929 to 1933 was
not much greater than in the depression of 1920-21, but the rise
since 1933 has far exceeded the recovery in wage rates after 1921.

These figures may be questioned on the score that they are money
rates and, as such, do not reflect changes in prices and the cost of
living.   As a matter of fact, if these figures are translated into what
we call "real wage" rates, the advance is even more striking and un-
precedented.   For real wage rates or the purchasing power of money
rates, were, in 1937, 50 per cent higher than in 1929.   This is ob-
viously a fact of prime significance and one difficult, if not impossible,
to match in the long history of American wages.

It is a fact, further, that takes on added significance when we
remember that the lengths to which we have gone to promote unionism
and collective bargaining and, hence, higher wages could only justify
themselves if these measures produced greater and more stable
employment.   But what does the record disclose on this point?
In each of the five industries employment and payrolls have failed
to respond to this heroic treatment of rising wages.   In several of
them employment and payrolls hardly exceed the levels of 1914.
And in all of them, it is quite evident that the price of labor in this
country continues to go up regardless of the state of business.

From this presumptive evidence it would seem to be hard for any
one to say that the right way to increase purchasing power is by
increasing the rate of wages.   Indeed the data point rather to the
conclusion that the rising price of labor in these troubled years may
have depressed both the volume of employment and of payrolls
and therefore, produced a result totally opposed to the desired one.

The second device we have used is public spending.   People
regard this device as an independent measure.   But it is not inde-

pendent. Spending and raising wages are closely related devices. As a matter of fact you could not use one without the other. You could not sustain wage rates in the United States at their present level if there were not governmental spending in huge amounts. As long as spending continues it may be possible to sustain the price of labor at its present artificial level and pay for it by perpetuating the unemployment of some 10 or more millions of our people.

It is not that we have not spent enough. For our spending, like our labor legislation and wage policy, has been generous and uninterrupted. A noted Swedish economist recently marvelled at the size of our deficit and annual appropriations for business recovery and the ineffectiveness of both. Tested by its results, the method of increasing purchasing power by public spending has failed as completely as the method of raising wage rates.

How these trends in American public policy will affect the position of civil servants and the employees of public utilities in this country seems to me all too clear. They are bound to make the problems of this class of employees more and more difficult. Unless the course of this policy is changed, and speedily, employees of government are likely to find that their wage rates lag far behind the rates of private industry. And unless the expenditures of government, central and local, are soon brought under a substantial measure of control, those who seek a livelihood and now find it in public service face the great danger of seeing their opportunities for work and wages severely and generally diminished.

Summary

In the beginning of these remarks, I pointed out that there is no major difference between the problem of labor relations in public service and in private employment. I also observed that a labor relations policy, whether it be applied to public or to private employment, has two major and simple objectives—first, the establishment of equitable machinery for the adjustment of grievances; second, the establishment of good conditions of employment, including satisfactory rates of wages. While, in the achievement of these objectives, we no doubt have much to learn from the experience of such countries as Sweden and England, it seems to me clear that the developments which occurred there, while significant, were largely colored by circumstances peculiar to each one of them.

In this country the most striking development of recent years is

the adoption of a fundamental economic policy which, briefly stated, has for its purpose the increase in the purchasing power of the American public.   The raising of wage rates and public spending, I have shown, are the essential elements of that economic policy.   It seems obvious that neither one of these methods has been successful in attaining the fundamental objective of increasing the purchasing power of the American public.   It should be noted, however, that in certain fields apart from those of public service the impetus given to organizing labor and increasing wage rates has established a differential in favor of these strongly organized groups which gives promise to penalize the less-organized groups, particularly those in the field of public administrative and technical service.

The management of public water supply in the United States, largely under municipal control, needs, therefore, if it hopes to maintain an economic status for its employed personnel that will command the services of competent individuals, to keep clearly in mind at all times the primary objectives of a sensible and workable system of labor relations, namely good conditions of employment which include satisfactory rates of wages and equitable machinery for the adjustment of grievances among employed personnel.   Water supply works managers and superintendents as a group, as well as all managers and superintendents in the entire field of public service, will discharge the responsibility which has been entrusted to them if they keep continually in mind the necessity under present social conditions in the United States for the development of an intelligent and rational labor policy in their departments and in their communities.   They will do well not to assume that successful management under modern conditions can be attained if clear thinking concerning labor conditions is not done by them.

Pipe Coating, Electric Drainage and Grounding Practice

By W. A. Johnson

THE CITY of Melbourne has a population of 1,100,000 persons. The water catchment areas lie some twenty to eighty miles distant from the city, and the water is conveyed in open concrete-lined channels, and pipe siphons, until the settled areas are reached. Supply to all parts of the city is effected by gravitation from reservoirs and service basins, through a network of 400 miles of wrought-iron or mild-steel trunk mains and 2,500 miles of cast-iron or fibrolite (asbestos-cement) distribution mains.

Railway electrification commenced in 1919, and was substantially completed by 1925. The system, which consists of 175 route miles of 1,500 volt d.c. rail-return electric railway, with open-ballast track, is served by 21 substations in parallel, with the rail connected to the negative bus, which is not earthed. Consistent with satisfactory operation, the machine voltage at each substation is maintained at a value which will minimize circulating currents, and allow satisfactory electric drainage. At railway-tramway crossings, insulated squares are employed, which are connected to either system, as required.

Tramway electrification commenced in 1906, but the greater part of the electrification was carried out in the periods of 1910–1916 and 1924–1929. The system, which consists of 125 route miles of 600 volt d.c. rail-return electric tramway, with concrete road-bed, is served by 23 substations. The rail is connected to the negative bus which is not earthed, but, in order to limit the rail drops, most of the substations are provided with a system of insulated negative

feeders. Owing to the track leakage resistance being much lower than that of the railway system, no attempt has been made to interconnect the two rail systems.

There is an extensive network of underground paper-insulated lead-covered telephone cables. While, at first, these were laid with no protection save wood troughing, many of the recent cables are in earthenware or concrete ducts. Some small laterals are laid in galvanized iron pipe and, although economical, this construction makes it more difficult to maintain the large cables negative to earth. Nevertheless, in the past ten years, the number of cable faults has been very considerably reduced by the use of electric drainage.

The networks distributing manufactured gas consist almost wholly of cast-iron mains which carry very little stray current. The earthing of electrical installations to gas mains or gas service pipes is absolutely prohibited.

In the metropolitan area, electric energy is distributed in the form of 230/400 volt, 3-phase, 50 cycle alternating current. For many years a separate 200-volt three-wire direct current network served the central portion of the city. The State Electricity Commission generates and distributes most of the domestic and industrial load and, through the Chief Electrical Inspector, is charged with formulating and administering electric supply safety regulations. Owners are responsible for electric supply apparatus and safety appliances inside the property.

40 Years of Pipe Coating Practice

Since 1886, all mains of diameter 18-inches or over, and some mains of less diameter, have been made of wrought iron or mild steel. The cost of these materials in comparison with that of cast-iron has generally been such as to render this the most economic course, but, in addition, in the large sizes at least, there has been the added advantage of the elimination of large destructive bursts to which cast-iron mains are subject.

The older wrought-iron and mild-steel mains have given, generally, very good service, comparatively free of trouble: but since about 1922, following the general introduction of direct-current traction on surface railways and tramways, the position has altered considerably. In certain areas, the cost of maintaining mild-steel mains has been very high owing to pitting and perforation, and the use of mild steel in these places is less justifiable economically. In the sizes

up to and including 9 inches diameter, both cast-iron and asbestos-cement are available, but for the larger sizes, even in areas where electrolysis is serious, practice has developed along the lines of mitigation (as by electric drainage) and protection of the mild steel by coatings.

The earliest coatings were a mixture of Trinidad asphalt and coal tar, applied by rotating the hot pipe in a bath containing the heated mixture, and then, when the coating had hardened but was still slightly soft, rolling the pipe over a sanded floor. Many of these coatings have been examined after 40 years of service. The asphalt on the inside is usually found to have broken down for its full thickness (except in rare instances where exceptionally thick) to a brown cohesionless substance; but, nevertheless, on scraping away this substance—which usually retains the original form of the coating, but is deeply rust stained and cracked and partly covered with nodules—the plate beneath is found to be in quite good condition. This is not generally so on the outside of the pipe. Coatings of this type varied greatly in thickness, and, except where the thickness approached $\frac{3}{16}$ in., it was usual to find that the asphalt had broken down for the full thickness and more or less damage to the plate had occurred. But where the coating was exceptionally thick, deterioration had not affected the full thickness of asphalt, and unchanged—or apparently unchanged—coating material was found adhering firmly to a surface still in perfect condition.

Mechanical Damage to Coatings Common

One very common cause of ineffective protection, even where the coating had originally been of sufficient thickness to be effective for a long period, was mechanical damage, in some instances due to handling (e.g., cuts, tool marks, etc.) and in others due to damage in the trench through attenuation of the coating on hard points, tearing of the coating due to shrinkage of the backfill, burning and ineffective repair of the coating at the lead joints, and so forth.

Many minor changes in practice took place over the years, until 1926, when for the first time the external coating was reinforced and shielded by wrapping with hessian (strong, coarse cloth of hemp or jute) drawn through the hot coating material. In principle this was an improvement, as it resulted in external coatings of more uniform and generally greater thickness; and, in the course of maintenance, pipes have been exposed in which protection by this type

of coating has been reasonably effective. But broadly speaking this change has not been outstandingly satisfactory. It is not easy to free hessian of all moisture, and even a small amount causes frothing and bubbling in the mixture which results in bubbles which sometimes penetrate through the coating to the steel plate. Another disadvantage of hessian wrapping is that in some coatings the fabric has been found to have pulled through the hot coating material in the process of application, and, coming into contact with the steel plate has in due course rotted and set up corrosive conditions there.

Asphalt Replaced by Coal Tar Pitch

As a result of investigations commenced in 1930, the use of asphalt as a coating material was abandoned and coal tar pitch, which does not deteriorate with time as does asphalt, and does not absorb water to the same degree, was substituted for it. The coating process, as it existed from 1934 to 1938, consisted in priming the hot pipe with horizontal retort coal tar, dipping it in hot coal tar pitch to apply a primary coating of about $\frac{1}{50}$-inch thickness, and then drawing on to the pipe one or two hessian wrappings, the hessian being first impregnated with hot tar, and then drawn through hot enamel, thereby building up a pitch-enamel-hessian coating up to about $\frac{3}{16}$-inch thickness. The enamel for this purpose consisted of a 60-40 mixture of coal tar pitch and finely ground limestone.

With strict control of materials and temperatures of pipe and baths, and of technique, this process has proved capable of producing good coatings, but after four years of critical examination the conclusion has been reached that the straight coal tar pitch and the pitch-limestone enamels are too susceptible to temperature, and the dip coatings too thin to produce reliable results without excessive care.

There is now in hand a contract for 25,000 feet of 46-inch main in which a new coating process is in use. Dipping has been abandoned, and a method of controlled mechanical pouring substituted, the pipe being rotated and traveled past rotary brushes fed, by pump, with paint for priming and past mechanically controlled pouring pots for internal and external coating. By this means the rates of application of primer and enamel are under control and any thickness of coating may be readily obtained. For the internal coating, the pipes are spun at about 60 to 70 r.p.m., and usually two runs are applied, totaling in thickness about $\frac{1}{8}$ in. For the external coating, the speed of rotation is low, two or more runs are applied, and, after

testing with a high-tension spark, and after flaws have been repaired, a wrap of paper felt impregnated with tar is wound on and stuck with a light application of hot enamel. The total thickness of the coating so applied is approximately $\frac{1}{4}$ in.

Except for the primer, which is a solution of pitch in naphtha, only one coating material is used—an enamel comprising 55 per cent coal tar pitch, 10 per cent asbestos, 17.5 per cent talc and 17.5 per cent limestone. This is far less susceptible to temperature than straight pitch or pitch-limestone enamel, and is tough and tenacious. Owing to a tendency to segregation of its components it cannot be used in a dipping bath, but it can be effectively handled in kettles with mechanical agitators, and is quite suitable for pouring. Coatings applied in this way are of substantial and uniform thickness, are tested all over, and from observation to date stand up well to handling, and do not shatter in cold weather or run in hot. When the pipes have been laid, the coating is made continuous over the joints by brushing on the inside, and on the outside by encasing the whole joint in enamel poured into a mould bolted around the pipe.

Using the four-electrode method, a survey of the electrical resistivity of the soil is made along the proposed route of each new main. In general, about 80 per cent of the perforations occur in areas where the soil resistivity is below 1,000 ohm-cm. units and in such areas the thickness of the external coating is increased. Typical values for the resistance of hessian-wrapped pitch-limestone enamel coatings, after 30 months in the ground, are 50,000 ohms per sq.ft. (single wrap) and 330,000 ohms per sq.ft. (double wrap).

Construction practice has also changed, the earlier riveted pipes being superseded by pipes of lock-bar construction. For many years now, all pipes have been fabricated by welding. The jointing of large mains is frequently effected by welding, but lead jointing, with or without cement mortar backing, is still widely practiced.

Electric Drainage Begun in 1926

As mentioned earlier, perforations began to increase rapidly about 1922, and, by the end of 1925, were occurring at the rate of more than eighty per annum. The average cost of repairs, including road repairs, is £21 ($78.50).* It has been found that these perforations can be conveniently recorded by mass curves, plotting total perforations against age of main. A separate curve is kept to show the

* Australian pound approx. $3.74, July, 1939.

history of each main in service, plotted on ordinary squared paper. These curves appear to have the general form $y = ax^b$, where a and b are constants which may be conveniently ascertained by plotting the curves on logarithmic paper; but this simple equation does not hold where the pipes are cement-lined (1, 2).

Since 1926, mitigation has been steadily applied, principally in the form of electric drainage, but also by means of cathodic protection equipment, zinc plates and cross-bonds. All these methods involve the use of insulated cables which are connected to the mains at appropriate locations.

The electric drainage bond is employed where a main, discharging stray current, crosses or approaches an electrified track. It consists of 19/.083 insulated copper cable, drawn through galvanized iron pipe which is then filled with coal tar pitch enamel. One end of this cable is provided with a steel tip, which is welded to the main. The other end is connected to the rail, to the negative bus or to a suitable negative feeder. The electric drainage bond is provided with suitable control equipment, switch, fuse, copper-oxide rectifier and adjustable resistance. The resistance is used to adjust the drainage current to a value which, without being excessive, is sufficient to protect the main; and the copper-oxide rectifier to prevent current entering the main, during intervals when the rail is positive to earth.

Where the pipe-to-rail potential is too low to overcome satisfactorily the inherent resistance of the copper-oxide rectifier, a transformer is added to the equipment. This transformer is energized from the electric supply mains, and usually has a secondary voltage between one and six volts. The complete arrangement is known as a boosted electric drainage bond.

Both types are adjusted initially, and from time to time, after examining charts obtained from recording millivoltmeters. In winter the resistance of the path between pipe and rail is lower than in summer, and, consequently, a value of resistance suited to one condition may not be satisfactory for the other. Again, as a main ages, the coating resistance decreases and a corresponding decrease in the adjustable resistance is necessary.

Cathodic protection has been adopted in two areas not suited to electric drainage. The equipment is similar to that used in a boosted electric drainage bond, except that the drainage cable discharges the current to suitably placed earth-plates, instead of to the rail (3). It is fed from the electric supply network and is designed to

maintain the affected water mains, and adjacent telephone cables and gas mains, 0.300 volt negative to earth. The equipment is operated continuously, preventing any possibility of corrosion arising from the interconnection of conduits composed of dissimilar metals, and is of the multiple-earth-plate type, thereby spreading the cathodic effect uniformly along the conduits. Installed in September, 1935, at a first cost of £280 (the charges covering interest, renewal, maintenance, and electric energy amounting to £35 per annum), the first cathodic protection unit is now showing a saving of £235 per annum. Whereas, prior to adopting protective measures, the cost of effecting repairs was £270 per annum, since December, 1935, no perforations have occurred in the area served by this equipment. This supports the view that a period of some six months is required in which to neutralize the corrosive environment formed by the corrosion products surrounding a pipe damaged by electrolysis (4).

In two other areas, where electric drainage is not practicable, zinc earth plates have been connected to the mains. The use of zinc plates, to render conduits cathodic, is suited only to cases where the required potential reduction is small, and is more satisfactory on telephone cable systems than on water supply networks. Being a form of cathodic protection, the equipment should, of course, be designed to protect all adjacent conduits.

Where two large mild-steel or wrought-iron mains are laid in the same street, stray current often tends to transfer from one to the other, particularly in areas of low soil resistivity. It is, therefore, the practice to cross-bond parallel mains in all such areas. The cross-bond consists of 37/.083 insulated copper cable, protected by galvanized iron pipe. Pilot wires are provided and, in addition, the bond can be opened for testing purposes.

In certain areas it has been found that the lead-covered telephone cables discharge stray d.c. traction current to the cast-iron distribution mains. This situation, which is often confined to a small area, usually arises where the distribution main is connected to a well-coated mild-steel or wrought-iron main, which has been rendered highly negative to earth by electric drainage. Three methods of meeting this difficulty have been suggested:

(a) Insertion of an insulating joint at the cast-iron branch, to isolate the distribution system from the large main. This method, of course, destroys the protection which the distribution main and service pipes acquire by virtue of their connection to the highly negative trunk main.

(b) Drainage of the telephone cable to the water main. This is usually the cheapest method, but it sets up the same unsatisfactory situation as arises where electric supply authorities rely on water supply service pipes for grounding protection (see below). Moreover, the interconnection of dissimilar metal conduits may result in serious damage by galvanic action, unless appropriate steps are taken to guard against such attack (5, 6).

(c) Drainage of the telephone cable to the traction network. This method is quite satisfactory. However, in some instances, boosted electric drainage will be necessary, and then the cost may be substantially higher.

As yet there has been no extensive investigation of the effects of alternating-current leakage, but it is known that some of the large mains carry appreciable alternating currents.

Grounding Practices

The distribution system, in which the pressure varies between 50 and 110 lb. per sq.in., consists mainly of cast-iron pipes. Since 1925, all new cast-iron mains have been cement-lined prior to laying; and many old mains have been lifted, cleaned, cement-lined and relaid elsewhere. Cement lining in situ has been practiced to a limited extent. The use of asbestos-cement mains dates from 1926, and, at the present time, a very considerable proportion of all distribution mains being laid is of this material, which is virtually non-conducting and, therefore, effectively isolates the water service pipe from the network of metallic mains. The cast-iron mains suffer external corrosion in certain soils, particularly where the electrical resistivity of the soil is less than 1,000 ohm-cm. units. When not cement-lined, they also exhibit tuberculation and internal corrosion which is usually more marked than the external attack.

Service pipes are the property of the consumer and must be laid and maintained in accordance with the by-laws of the water authority. Between 1898 and 1921 the use of either lead or galvanized iron piping was permitted, in 1921 galvanized iron piping was made compulsory, and by 1928 the service pipes were mostly of this material. Lead piping is easily damaged mechanically, has a high electrochemical equivalent and may be subject to galvanic attack in the presence of cast-iron (5). On the other hand, in Melbourne, the life of galvanized iron piping is not great (say, 12–15 years) on account of internal corrosion and incrustation.

In 1928, the use of copper piping, which is not affected by incrustation, was permitted; but, owing to the cost of this material, comparatively few copper service pipes were installed. In 1936, in order to reduce the damage to modern road surfaces, caused by the frequent openings, it was decided to make compulsory the use of copper piping between the main and the building line.

Because the effects of stray current, originating in the railway and tramway electric traction systems, were then known to be serious in many parts of the metropolitan area, and had caused extensive corrosion on the trunk mains, it was anticipated that the discharge of a portion of this stray current through the distribution mains and service pipes would result in severe damage to copper piping, on account of its thin wall and relatively high electro-chemical equivalent. It was accordingly decided that two insulating couplings, one at the main ferrule and one at the building line, be incorporated in all new copper services: with the proviso that, if the service were fed from a fibrolite (asbestos-cement) main, the coupling at the main ferrule could be omitted. It was anticipated, also, that the insulating couplings would prevent galvanic action due to dissimilar metals, either at the main, or at the building line (6).

For many years, electric supply equipment had been earthed to the mains and service pipes, with the knowledge of the water supply authority, but without permission having been obtained or sought. Known as the "direct earthing system"—the neutral of the distribution transformer was grounded to a substantial earth-plate, or any cast-iron water main in the vicinity, and the metal conduit, housing the insulated conductors at each property, was connected to the water service pipe. There was thus made available, from conduit to transformer neutral, a path of low resistance—usually less than one ohm—which carried current only under fault conditions. Any failure of insulation, tending to make the conduit rise to a dangerous potential, was accompanied by a heavy flow of current, sufficient to operate the service fuses which then disconnected the supply.

With the introduction of asbestos-cement pipes, in 1926, the resistance of the path from the electric supply conduit to the transformer neutral was increased, but not to any material extent, because, in general, the service pipe (often more than 60 ft. in length) had a low resistance to ground. However, where a very short service pipe was connected to an asbestos-cement main, there was a possibility

that the fault current would be insufficient to operate the fuses. Moreover, where an asbestos-cement main was laid past the distribution transformer, it was necessary to rely on earth-plates to ground the neutral.

At a city wharf, the insulation of an air-compressor motor, operated from the direct-current mains, became impaired. The frame of the motor was carried on the wharf timbers, and was earthed to a galvanized-iron water service which, after passing through six feet of soil, was connected to a fibrolite main. Whenever the motor operated, the pipe became 90 volts positive to ground, as was quickly discovered by the plumber called in to effect repairs, and was completely destroyed in four months.

With the introduction of insulating couplings, in 1936, the earthing problem became more acute, for, at properties supplied through copper piping, only the portion of the service pipe laid inside the building line was available for earthing purposes. Moreover, in the case of shops and premises which abutted on the building line, the internal service pipe was often laid almost wholly above ground and had little or no earthing value.

The position was discussed with the State Electricity Commission and the Chief Electrical Inspector. It was recognized that, where it was common knowledge that property owners were relying on the water service pipes for protection, there was a duty to give notice to affected persons so that they could adopt other satisfactory measures, and that the liability for accidental damage remained until a reasonable time had elapsed, in which the owner could adopt these measures.

This liability, which was confirmed by the opinion of Counsel, arose where the water authority either disconnected a service already earthed through a metallic main, and reconnected it to a non-conducting main, or renewed such a service, inserting insulating couplings which previously were not in use, or compelled an owner to do so. A procedure was accordingly devised involving co-operation of the authorities concerned, and providing effective notice being given to the owner.

The situation, insofar as it affected electric supply practice, could be met by either of two systems: the "multiple earthed neutral system," already introduced in towns having non-metallic underground pipes, or the "earth leakage system," developed for rural electrification in Europe (7).

In the multiple earthed neutral system, the neutral conductor is utilized to return the fault current to the distribution transformer, but, in order to guard against the protective system being rendered inactive by accidental open-circuiting of the neutral conductor, an alternative path is provided by grounding this conductor to the water service pipe at every installation. This system has disadvantages. Where the neutral conductor is accidentally broken and the live conductor remains in good order, or where the conductors are transposed by accident, the electric supply conduit and the water service pipe may rise to a dangerous potential, if the soil resistivity is high, and the water service pipe has non-conducting sections. With this system, the water supply net work and the neutral conductor form parallel electrical paths, so that the return current, or even stray current, will divide between them in a proportion determined by the ratio of their impedances, which is quite a different position from that which arises from the direct earthing system, where the water pipes carry electric supply current only under fault conditions. With the rapid progress now being made in plastics, synthetic rubber compounds and other non-metallic materials, it is possible that a satisfactory non-metallic water service pipe may be developed in the near future, necessitating a modified multiple earthed neutral system, in which separate earth-plates provide grounding of the neutral conductor.

In the earth leakage system, the conduit housing the live conductors is connected, through the earth leakage trip coil, to a buried earth-plate, and the system will operate even when the earth-plate resistance is as high as 800 ohms. When the conduit rises above a predetermined potential, current passing through the trip coil operates the earth leakage switch, and this cuts off the supply of electric energy to the property. The usual earth leakage switch can be installed for £3. Although preferable from the point of view of the water supply authority, this system is not completely satisfactory. The switch, being a delicate mechanism, is provided with a test button, which should be operated monthly by the occupier or the meter-reader, to ascertain whether the apparatus is still in good order. Being extremely sensitive, the switch lacks the selectivity necessary for complex electrical installations, and may be energized by surges associated with severe atmospheric electrical storms.

After due consideration, the electric supply authorities adopted for the time being the direct earthing system, supplemented by

the earth leakage system, the conduit housing the live conductors being connected to the water service pipe and, through the earth leakage switch, to a buried earth-plate.   It was expected that under normal conditions the direct earthing system would operate, that surges would be diverted to the direct earthing connection and would not operate the earth leakage switch, and that, if at any later time the pipe system became electrically unsatisfactory, the earth leakage system would then provide protection.   This system, however, still leaves the earth leakage switch subject to external disturbances. At an overline bridge, carrying a cast-iron gas main and a fibrolite water main, the electric traction contact wire became accidentally short-circuited to the structural steelwork.   The gas main (which was resting on the girders) and its connected service pipes became highly positive to earth, and at neighboring properties where the water and gas services were making contact (e.g., through gas hot water systems), the water pipes and the electric supply conduits also became highly positive to earth, and caused the earth leakage switches to operate and disconnect the electric supply.   This instance, which would not have occurred if the earth leakage system alone had been adopted, illustrates the complications which can occur through inter-connection of water and electric supply networks.

Inter-Utility Protection Unreliable

While, at present, there appears to be no simple solution of the grounding problem, it will be clear, from the foregoing paragraphs, that it is an undesirable practice for one authority to rely for pro-tective purposes on the system of another, when this involves the presumption that the latter system will remain indefinitely un-changed.

Some years ago, at the principal automatic exchanges, it was the practice to employ earthed circuits to feed private branch ex-changes in large office buildings.   The current, often 10 to 15 amperes, was fed to earth from the positive pole of the exchange battery, picked up at the subscribers' premises, and then returned to the exchange by insulated metallic conductors.   Instead of employing an earth-plate to discharge this current to ground, the positive pole of the battery was invariably connected to the water supply distri-bution system, and, because it offered a highly-conducting path, the 3-inch fire service pipe entering the exchange was usually selected when making this connection.   This practice, which was unknown

to the water supply authority, resulted in the cast-iron distribution main becoming two volts positive to earth. The serious situation arising from this practice was not disclosed until a plumber reported that he had renewed a water service pipe in the vicinity six times in three years. The telephone authority immediately abandoned the practice of earthing to the water supply system and laid a substantial earth-plate at each exchange. This arrangement, however, had disadvantages in that, while the current put into the earth caused rapid deterioration of the earth-plate and, entering the neighboring telephone cables and water mains, caused corrosion farther afield, the very fact that the telephone authority employed substantial earth currents reacted adversely, when claiming compensation from the traction authorities for failures caused by electrolysis. Shortly afterwards the telephone authority adopted the practice of making private branch exchange circuits completely metallic.

As a safety precaution, at all electric tramway car sheds, it is the practice to ground all structural steelwork to the rails. Since fire sprinkler pipes are invariably in contact with the structural steelwork, the net result is that the rails are connected electrically to the water supply distribution system. If the sheds are situated in a rail-positive area, this practice will result in severe corrosion on the neighboring mains and service pipes, but the possibility of this happening has now been eliminated by inserting an insulating joint, in the form of a short length of hose, in the supply pipe serving the sprinkler system.

On all bridges and similar structures it is considered advisable to insulate the water mains against contact with the steelwork. In one instance, a 4-inch cast-iron distribution main, resting on the mild-steel decking of an overline bridge, was severely damaged, and repairs required several days, when the live conductor of the electric traction system became accidentally grounded to the structural steelwork. The bridge was some distance from several substations, which fed into the fault, and the short-circuit current, which persisted for some time, flowed along the main to ground and melted twenty lead joints.

References

1. LOGAN, K. H. Engineering Significance of Soil Corrosion Data. N. B. S. Journal of Research, **22:** 109 (1939).
2. LOGAN, K. H., EWING, S. P. AND DENISON, I. A. A. S. T. M. Symposium on Corrosion Testing Procedures (1937).

3. SCHUMP, R. R.   Controlling Electrolysis.   Electric Journal, **36**: 59 (1939).

4. RHODES, G. I.   Electric Pipe Line Drainage—A Practical Alternative to Reconditioning.   Electric Journal, **33**: 91 (1936).

5. FORNES, J. G.   Electrolytic Corrosion of Lead Pipes by the Action of Currents of Galvanic Origin.   Boletin. O. S. N. (Buenos Aires), **1**: 625 (1937).

6. ALLYNE, A. B.   The Dissimilar Metal Problem in a Distribution System. Fourth Conference on Underground Corrosion, N. B. S., Nov. (1937).

7. GILBERT, T. C.   *Artificial Earthing for Electrical Installations.*   (1932).

Discussion by *Charles F. Meyerherm*.*   In general, Melbourne's stray current corrosion and mitigation experiences closely parallel those of this country. However, the transportation utilities there apparently took advantage of existing knowledge and experience, and so avoided many of the mistakes made in the original installation of electric railway and railroad systems in the United States and other countries. The Melbourne electrified tramway or 600-volt trolley system started operation in 1906 and now comprises 125 route miles served by 21 substations, while the electrified railroads started in 1919 now comprise 175 route miles served by 23 substations. The existence of such a high ratio of substations to route miles, indicates that the significance of one of the primary factors in the control of stray railway currents and resultant electrolytic corrosion was appreciated and included in the design. This is further exemplified in the case of the 600-volt tramways, where insulated negative feeders are used with an ungrounded negative bus to supplement the track conductivity and reduce track drops. These two essentials constitute the crux of the conclusions of the 1921 report of the American Committee on Electrolysis, but American electric railways have been much more restrained in applying them.

Use of Asbestos-Cement Pipe

It is also interesting to note that while the sub-surface structure systems of Melbourne are very similar to those existing in American cities the use of cement-asbestos pipe up to 9 inches in diameter has been increasing rapidly since 1926 and is now very general. This type of pipe practically eliminates corrosion difficulties but it does introduce complications in the electrical grounding problem.

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The use of electrical drainage on the wrought-iron and steel trunk water mains appears to have afforded a certain amount of electrolysis protection to these mains but necessitated similar protection for other neighboring underground metallic structures in order to prevent electrolysis action between drained and undrained structures. This is in line with American experience and where there are numerous underground structures the multi-structure drainage system becomes correspondingly complicated.

Varying Resistance of Lead-Caulked Joints

On the cast-iron mains corrosion trouble has developed in the areas where such mains connect to drained wrought-iron or steel trunk lines. This has undoubtedly occurred because of the relatively high resistance of the joints in the cast-iron lines. Few people realize that lead caulked joints in cast-iron pipe lines may vary in resistance from a low value which approximates the resistance of a few feet of continuous cast-iron pipe, to a high value which may exceed the resistance of a mile or so of continuous pipe. Data in the writer's files show that for a total of 247 joints tested, the average resistance of a lead caulked joint equals 385 feet of continuous pipe with the lowest value 3 feet and the highest 6,135 feet of continuous pipe. Substantial potential differences can therefore be built up across these joints, and in the case of a few moderately high-resistance joints in a cast-iron line near the point where it connects into a drained line, these potentials can cause rapid corrosion of the cast-iron pipe.

The Melbourne tramway and railway electrifications are not very old, so that the apparent immunity of the cast-iron pipes to electrolysis corrosion may be somewhat misleading. On account of the greater wall thickness of cast-iron pipe as compared to wrought-iron or steel, and the difference in character of the corrosion product, considerable damage to the cast-iron mains may have taken place, even though there has been little trouble due to actual failures. In the case of the cast-iron gas main system the fact that very little stray electric current has been found thereon may be explained if cement joints are used on these mains instead of lead.

It is interesting to note that some of the large water mains in Melbourne are known to carry appreciable alternating current. This is rather unusual because with only a single ground on the neutral at the transformer, there should be little or no tendency for current interchange over the water pipes. In this country, where the multi-

grounded neutral is common practice, the ground wires and water service to individual houses carry from 25 to 75 per cent of the electric load in those houses and substantial current on the mains naturally results. Such currents and their possible effects on the pipes and the water itself are being studied by the American Research Committee on Grounding. This Committee would be interested in the results of any similar study undertaken in Melbourne if and when such an investigation is started.

Protecting pipe or other metals against corrosion by coatings is an old but still very popular remedy. The difficulty with the method lies in the inability to get and maintain 100 per cent coverage of the pipe and its joints under the conditions of handling, temperature, soil stress, moisture, etc. to which it will have to be exposed. An effective coating must not only be perfect in the pipe yard, it must remain so until and after it is in the ground. It must resist all manner of mechanical abuse and remain tough, flexible, impervious to moisture, and closely adherent to the pipe in spite of age, and numerous other deteriorating effects to which it is subjected. The development of pipe coatings in Melbourne has paralleled similar work in this country, and Mr. Johnson refers to the use of cathodic protection on pipe lines to supplement coating. This also coincides with American practice particularly on important and more or less isolated pipe lines.

Variation in Distribution Voltages

In connection with the electrical grounding or "earthing" problem as it is known in Australia, it must be pointed out that secondary distribution voltages in Melbourne are 230/400 volts compared to the 110/220 volt distribution common in this country. This means that for a given wattage load, the normal currents are one half as high as in this country, while surge currents due to faults may be twice as high. With the higher line to ground voltage the importance of reliable protection is considerably enhanced and the Australian grounding problem is radically different from ours.

The "direct earthing system" formerly employed in Melbourne differed from the system used in the U. S. because the neutral conductor was grounded to a water main or substantial ground plate *only* at the transformer. At each house, the house electrical conduits and through them the non-current carrying metal frames of machines and appliances, etc. were grounded to the house water service pipe. With the advent of cement-asbestos water mains and the installation

of service insulating joints in copper water service pipes to protect the latter against stray direct current electrolysis, "direct earthing" lost its effectiveness and actually became a source of serious hazard, since all house conduits, appliance frames and pipes might in case of a fault be indefinitely maintained at a potential of 230 volts to earth. For this reason, other means of protection had to be considered.

Earth Leakage Switch Method

A multi-grounded neutral, similar to ours, was suggested but with non-metallic water mains and/or insulating joints in water services this could set up dangerous potentials on not only the conduits, etc. of a house but also all of the pipes if the neutral conductor to that house became broken while the line conductor or conductors remained intact, or if the line and neutral conductors were transposed. These hazards lead to the consideration and use of the so-called earth leakage switch method of protection. This method has been used to some extent in Germany, and it involves a circuit breaker type of switch in the main alternating current supply to each individual meter. This switch has a voltage trip coil connected between the house conduits, pipes, etc. and a driven rod or a buried plate ground and so designed as to trip out the house supply whenever the voltage between the house conduits and general earth exceeds a predetermined value of say 12 volts. The driven rod or buried plate ground can have a fairly high resistance (up to 800 ohms) without interfering with the protective operation of the switch. A large number of these switches have been installed in Australia and they have been reasonably successful in service. The switches, however, cost money to install, they have to be tested frequently, and they have to be maintained. In multi-family buildings and in the event of lightning disturbances the switches are open to certain operating objections, so they have never received serious consideration in this country.

In connection with the grounding situation as a whole, Mr. Johnson makes several comments which are very interesting, particularly to American water works operators. In the first place, he foresees the early development of non-metallic service and house pipes which would necessarily upset all grounding practices. In the second place, he very clearly states "that it is an undesirable practice for one authority to rely for protective purposes on the system of another, when this involves the presumption that the latter system will re-

main indefinitely unchanged." In this country the electrical distributors not only rely on the water system for protection but they do it by devious third and fourth hand means (the property owner's electrical contractor), in order to relieve the electrical utility of any and all responsibility in connection with the ground connections. This lack of a definite responsibility for ground attachments is the source of much of the trouble and dissatisfaction with present practices in America.

Public Relations

By Marion L. Crist

WHY should a monopolistic utility be interested in building up friendly relations with its customers? They cannot go elsewhere to buy, and they will not use more of the utility's product just because they like it. That is what most utility operators thought a decade or so ago, but for some strange reason, or is it so strange, most of those belonging to that school of thought are now out of business.

Do you know why people complain most of all about taxes and next most of all about utility rates? They do, you know. They complain a lot more about water rates than they do about the price of bread in spite of the fact that bread costs 6.4 cents a pound and water, delivered inside your home in any quantity day or night, costs only four one-thousandths of a cent a pound. The reason is the same one that makes small boys hate to wash behind their ears and that made thirteen little unheard of States with the assistance of a certain Mr. Washington undertake to lick the then greatest nation in the world. The reason common to all of these phenomena is that people hate to do that which they are told they have to do.

People can go to any number of stores and buy bread. When they do go, they select a store of their own choosing and enter of their own free will. Incidentally they have a flattering feeling of importance at having made their own decision and at having their own money to spend as they choose. But when they pay their water bill, they have to come into your utility office and pay your price; or if they do not, their water will be turned off. And so they come in with a chip on their shoulder, ready at the slightest provocation, and in all sincerity, to tell you exactly what they think of you and of your service.

Therefore, there exists a more difficult public relations problem in the utility business than in any other. In most businesses the customer is at least open-minded, but in the utility business by the very nature of things he is quite likely to have either a definite or a subconscious feeling of antagonism.

Does it matter much to the utility? It would appear that it matters a great deal. First, from the purely selfish standpoint of the utility employee, poor public relations force changes in ownership in privately owned institutions and changes in personnel in publicly owned ones. If enough consumers dislike you, you had best start looking for another job because you are going to be needing one. But there is another and sounder reason than that from the customers' viewpoint.

A kindly feeling of respect toward the utility, its rates, and its service on the part of the consumers will increase sales. Certainly you recall buying more pump packing, cast-iron pipe, or razor blades than you needed for immediate consumption because you felt that you were getting a bargain. Just so will Mr. Jones give the roses an extra sousing once in a while if he believes he is getting a square deal from the water plant and, to a lesser degree perhaps, the manufacturer will use city water instead of drilling his own well. The increased sales will reduce the unit cost of furnishing water which will in turn, in the municipal plant at least, occasion rate reductions so that in the end the consumer will benefit from his own good will.

Down in Little Rock there exists a splendid example. At present the new Municipal Water Works is earning just enough money to pay all its operation and maintenance expenses, the interest and principal on its bonds, and all of the surplus commitments under its bond indenture. The Water Commission firmly intends to make a rate reduction in 1941, which is the earliest date that the bond indenture permits the making of a reduction. Since present revenues are just ample to meet commitments, the amount of that reduction will depend entirely upon increased sales during the next two years. If by building up public good will sales can be increased one fourth, which is not at all unreasonable because present per capita consumption is very low, then a very material rate reduction will accrue to the water consumers. Thus not only the utility employees but the consumers themselves benefit from proper business relations between the utility and its patrons.

The building up of proper public feeling is a tedious process. It

involves first of all adequate service at reasonable rates. A very
fundamental principle of our American Government is that in the
long run the judgment of the people is sound. They cannot be hood-
winked. Do not skimp on service, or inflate rates, to the value of
thousands of dollars and then donate hundreds to the Community
Chest or to free street showers for the kids in the summer and expect
the public to applaud your generosity. They may for awhile if the
accompanying advertizing is high-powered enough, but a day of
reckoning will come. Utilities have no special exemption from the
fact that honesty pays. If service is poor or rates are unreasonable,
find some means of correcting them.

Keep Up Appearances

Another important element is the physical appearance of the
property. The business office should be arranged to create a feeling
of pleasant friendliness on the part of the patron who comes to pay
his bill. Wicket windows and brass grill work are poor. They
create an impression of formal prudishness. Open spacious counters
for the paying of bills with business desks and comfortable chairs for
those who come to sign contracts or transact other business are
desirable. The office should be light, clean, and neat, creating an
atmosphere of efficiency but not one of formality or luxury.

Other parts of the water system can well be made attractive.
Pumping and purification plants are naturally interesting. They
can be made more so and can be beautified by landscaping and
planting that cost very little. Seats should be arranged about the
grounds particularly in shady or panoramic points; and near lakes
or reservoirs picnic and camping areas should be provided. Land-
scaping and the beautification of utility properties is a sound in-
vestment and will pay substantial dividends.

The simple aerator oftentimes offers splendid opportunity for the
development of a point of interest. A good example is the aerator
at Fort Dodge, Iowa. Upon entering the plant through a spacious
door at the head of a low flight of steps one is immediately confronted
with what appears to be a natural cascade flowing downward and
forward over native rocks. Just before the water reaches the huge
plate glass window, through which the brown rock and the swiftly
flowing water are visible, it drops from sight. Submarine lights add
to the attractiveness of this unique aerator.

Out in Los Angeles on warm summer evenings one of the main

thoroughfares to the beach is frequently crowded with cars slowing down to watch the play of many colored lights upon a beautiful fountain. The lights are constantly changing and the spraying water of the fountain assumes each new hue with remarkable effect. The fountain was installed by the City of Beverly Hills for the benefit of passers-by. Whether or not it has increased water sales, it certainly creates the impression that that water plant is operated by cultured people who enjoy a thing of beauty.

There are many other outstanding examples, some of them much more elaborate. You may not be able to afford a fountain or a new aerator but flower beds, green grass, and shrubbery are not expensive. Some beautification is possible and will pay in almost every plant.

Selecting Personnel

And now if rates and service are correct and the most has been made of the physical aspects of the plant, what can the utility do to forward the creation of good will. First, careful selection of all personnel that is commonly in contact with the public with ability to meet the public in mind is essential. Collection tellers, contract men, complaint men, telephone operators, meter readers, and field service men are all vitally important public relations positions. Only men with real ability to meet the public should be in these positions and their salaries should reflect that ability.

All personnel should be thoroughly acquainted with physical facts about the water system and about the policies and aims of its management. The combined personalities of Julius Caesar, Dale Carnegie and Sally Rand could not sell a thing about which they knew nothing. It simply cannot be done Each employee is a potential salesman of respect and good will for the water plant. Failure to provide him with facts will completely destroy his value in this field, and it will do more, too: it will insult his intelligence, belittle his position in the organization, and leave him without incentive or enthusiasm. Group meetings of the employees to discuss the water plant, its problems, and its aims are of tremendous value.

Next, it is absolutely essential that the employees themselves have a deep seated conviction of fair dealing and respect for the utility to which they are devoting their services. To do so they must receive adequate pay. They must work under pleasant conditions and with a very minimum of friction between themselves. They must be made to realize that they are an important element in a co-

operative enterprise.   The relationship between employees from the
highest to the lowest must be one of sincere, friendly, mutual respect.
The hard-boiled driving boss went out with the rest of boorishness
and ill-breeding in business, just as did the discourteous employee.

In a municipally owned plant the employees can be made to realize
that they are public servants and that as such they have a definite
and important obligation to fulfill.   Such a realization in addition to
giving the employee a sincere respect for the business in which he is
engaged gives him, also, a just feeling of importance for himself.
It makes him a better employee to try to live up to that importance.
Keeping an ample supply of pure water in all of the homes in a city
under all conditions of weather and time is an important job.   Add
to that the fact that proper handling of the water plant will result
in more water per dollar of the consumers' money and, therefore, a
more beautiful city, or in innumerable other worthwhile accomplish-
ments; and the utility employee's job becomes one of real service.
He is important and he should be made to realize it.

All employees, particularly in a municipally owned plant, should
remember under all conditions that the customer is likewise the owner
and employer.   The customer is entitled to all of the courtesy and
service that can be given him.   His opinion is the opinion of the boss
and as such should be assumed to be correct.   It is surprising how
often it is correct when one starts out on this assumption,—yes,
even about high bills.   Of course, he should not be given the cash
register, but he should be given satisfaction if it lies within the realm
of reasonable possibility.

Turning Mistakes to Some Advantage

It is an interesting fact that mistakes and emergencies are not
infrequently an aid in building good public relations—not, in any
sense, that they should be made or created with that end in view,
but once they occur they can quite often be used to make a sincere
friend.   An honest mistake, if it is not too serious, is not a crime.
It merely makes the consumer realize that the water plant is operated
by human beings like himself.   If the mistake is readily admitted,
properly corrected, and sincere apologies are offered, it not only
flatters the consumer but it leaves him with a conviction that an
honest effort is being made to serve him well.

Recently in Little Rock a major break in a 24-inch main occurred
the day after the main had been cleaned.   It had been necessary to

shut off approximately one hundred customers for a portion of one day and most of the second day in order to clean the main. Then the break occurred which necessitated keeping them out of water the whole of the third day, without notification. That is a serious failure. Those people could justly have been quite severe about it. To reduce their inconvenience to a minimum the Municipal Water Works hauled water to them in bottles until the main was put back into service. At every opportunity those customers were made to understand that the Water Department realized it had failed them badly. When possible a remark was made which let them know that the department forces had been hard at work for forty-eight hours straight to get their water back on. When it was over, public acknowledgment of the splendid way in which those people had suffered their inconvenience was made in the newspapers. Do you think the department lost many friends? Actually they made many new ones. The Little Rock Municipal Water Works was and is sincerely sorry those customers were out of water; but since they were, the opportunity of rendering extraordinary service was used to make friends.

Another way of making friends is by inviting visitors to witness the utility's operations and then making their visits interesting and enlightening. The operators should be trained to make visitors feel welcome. They should know how to present the interesting features of their plant. Seats, drinking fountains, and attractive places are essential. The superintendent of the filter plant at Wieser, Idaho, enjoys growing ferns and semitropical plants. His operating gallery is full of them. It is an attractive place, particularly in those long cold northern winters. He has used his hobby to invite visitors and build good will.

Municipal Advertising Justified

Advertising is just as essential to a monopolistic utility as to the corner grocery store. Remember, people are not antagonistic to the corner grocery, but they are to the utility. Most modern privately owned utilities do advertise. The Bell Telephone Company is a splended example. Surprisingly few municipally owned plants do so effectively. Perhaps they feel that the consumer's money should not be spent to try to sell him more water. That is foolish. A few dollars spent in educational advertising, in most systems, will

return to the consumers many fold in reduced rates, more water for their money and other benefits.

Utilities have a powerful inexpensive medium of advertising at their command. Usually once a month, or at least once a quarter, they send a message into the home or office of every consumer on their system. Perhaps they send a card bill. If so, it will cost only a little more to make it an envelope. In the envelope they can enclose a bit of advertising, a picture of the plant, a suggestion about a new rate or some other interesting fact, and thus reach every customer on the system for a fraction of a cent apiece. A reasonable investment in this and other forms of advertising is absolutely sound both from the standpoint of the consumer and his utility.

The handling of complaints is vitally important in the development of good will. In a sense it is a negative measure; it prevents bad will. However, as in the case of emergencies and mistakes, a complaint can many times be turned into a boost.

Every complaint which comes to the attention of any employee of the utility, no matter how trivial it may be or how wrong it may appear, should be investigated and if possible corrected. Complainers are like spoiled apples in a barrel; they spread rapidly. Therefore, everyone discovered should be eliminated if possible.

No definite procedure can be established for the handling of complaints. People are not alike, and that which satisfies one may not do so with another. In general, it is important that the consumer's viewpoint be adopted so far as possible. View the matter in his eyes and then do that which would please you in his situation. If there is no possibility whatever that his complaint is just, tell him so quietly and courteously and explain why it is impossible. If there is any possibility that the utility is at fault, and they all do make mistakes, then leave no stone unturned in determining the truth.

The creation of proper public relations in the utility business is a difficult many-sided problem. There is no royal road to its achievement. Perhaps the one maxim which covers as much of the field as any single one can is: "Under all conditions do that which appears to be to the best interests of the customers as a whole, and be a gentleman while doing it."

Telling the Water Purification Story to a Non-Technical Audience

By Martin E. Flentje
Illustrated by H. W. Montague

THE opportunity to talk about water to any group or club should be readily embraced by any water works man who is given such an invitation. Water is essential to life, and its delivery under pressure with unfailing continuity of service in an attractive, palatable and pure state is a job any of us can be proud to be connected with, and one which should properly interest our fellow townsmen. Such an invitation to talk will present an opportunity to boast a little about one's industry, about which, incidentally, very little is known by the general public. Its near 12,000 organizations provide a healthful and needed product to 80,000,000 people in the United States, making it an industry of significance. Its estimated annual income of $450,000,000 is somewhat below the $800,000,000 cigarette industry, but puts it into a class with such important and sizable products as butter, boots and shoes, canned foods, and places it well above the industries enumerated as caskets, coffins (income $94,738,-000) or chewing gum ($47,766,000 in 1935). The industry's 60,000 to 75,000 employees place it in the men, youths' and boys' clothing, glass, and confectionery classes. These figures indicate that water supply is not only a large and important business, but also that it is an integral part of our economic life.

The author of this paper is not, however, qualified to tell the story of more than a small portion of the water supply business. This small part, possibly because of its association with the now popularized sciences of chemistry and bacteriology, does appear to interest people greatly and is easily presented. Experience has shown that it is not at all necessary to be an orator or even an accomplished speaker to make this phase of the business interesting enough to be showered with questions after a talk about it has been presented. The following material, then, is primarily concerned with the telling of the purification side of the story of water supply.

Some brief "don'ts" should be emphasized and the writer apologizes for being presumptious enough to present them. If your audience happens to be a luncheon or dinner club, and your meal with them doesn't taste very well and you find yourself nervous, don't worry, for this is a natural reaction even for speakers with wide experience and will correct itself when you once get up on your feet to talk. Don't make your talks too long—a talk before a service club five minutes shorter than the allotted time will be much more favorably received than one lasting five minutes overtime. Don't feel it necessary to tell a funny story. Unless you are a better raconteur than the average person, your story will have been heard by many and will not appear very funny to the remainder. Moreover, water purification is too interesting and important a subject to justify wasting any time on two not-so-funny Irishmen. Don't try to orate or worry a great deal about your delivery. Speak naturally in a conversational tone of voice that is loud enough for all to hear, and talk as though you were conversing with your neigh-

bor, telling him about your job and work in which he has shown an interest.   Above all, *don't read* your talk!

Now you have been introduced and are on your feet—on your own, as it were.   The Chairman's introduction has quieted the room and secured some attention for you.   It is necessary that this first interest in you as the speaker be continued and converted and intensified to include the subject of your talk.   Some speakers use the funny-story-beginning to gain further attention, with the often disappointing results hinted at in the previous paragraph; others use some more definite attention-pulling scheme.   For our particular purpose, the magic generally associated with the science of chemistry may serve the desired purpose.   Changing plain water to "wine" is no trick at all with phenolphthalein indicator and a water treated beforehand to contain carbonates and hydroxides; yet such a stunt, if performed in shiny bright beakers, is certain to introduce the subject in a spectacular manner.   The stunt can be continued by making the Chairman your accomplice, asking him to blow through a glass tube into the water to recarbonate it and cause the "wine" to become water again.

In this manner a magician might introduce water, and indeed it would be appropriate for a magician to make a talk on water—not only would it require magical powers to tell all about water in the short period usually allotted to a speaker, but only a magician could do justice to this compound.

Indispensable to life, it is generally casually accepted as God's gift to man, but is only really appreciated when it becomes impaired in quality or quantity.   It makes up a large part of our person (75 per cent), and is a constituent of all food.   In spite of periods when we are aware of its near absence in droughts and dry spells, it is surprisingly abundant—so much so that if all of the earth's mountains and ocean depths were levelled off, the entire world's surface would be covered with water to a depth of approximately 2 miles.   It possesses properties that emphasize its magical character; its familiar formula H_2O represents but one of its many forms; in all, 33 formulae are required to cover its various combinations, all of which, however, contain the elements hydrogen (H) and oxygen (O).

Water is the most common and probably most efficient of firefighting substances, yet this would hardly be surmised from an examination of its components.   Hydrogen, as shown in the Hinden-

burg disaster, is a highly inflammable and explosive gas, and without oxygen, the other component, no combustion or explosion could take place. The cheapest and least publicised of utility services, it became suddenly famous several years ago when its prodigal son "Heavy Water" was first discovered—this compound then so expensive to produce that thousands of dollars were paid to obtain only a few ounces of it, and which later became relatively cheap at $25,000 a quart! Its properties affect our climate as our New Jersey shore communities well know; not so well known is the fact that an unusual reversal in its character has made it possible for us to survive and live in this climate. Water when it becomes colder becomes heavier, this continuing until 4°C. (39.3°F.) is reached, when suddenly further cooling results in its becoming lighter. This is the reason why our rivers and lakes freeze from the top down, rather than from the bottom up. Freezing from the bottom up would result in huge blocks of ice and glaciers with accompanying arctic conditions and probably human annihilation.

This, then, is water—an oddity intensely interesting, but actually not the product we sell and serve. The water coming from your household faucet is still God's gift to man with all its natural characteristics preserved, but modified and improved to meet the requirements and conditions of modern living. It is a manufactured product, produced in such quantities that your pumping station and purification plant is probably the biggest "bulk" plant in town. It is also peculiarly a product of the community; it has probably never occurred to your listeners that they, without thinking, use the terms "Wanaque Water," "Atlantic City Water," etc., thereby unknowingly recognizing and acknowledging the difference in these supplies. Such differences are caused by the presence of minute concentrations of dissolved mineral matter, the change from a water having the composition 99.998 per cent H_2O and 0.002 per cent dissolved matter to one with 99.800 per cent H_2O and 0.200 per cent dissolved material, approximately representing the difference between the Nation's softest and hardest municipal supplies.

Your hearers are perhaps anxious by this time to have you start getting down to cases and telling them about what is done to the water delivered to them. The extent to which this is gone into will naturally depend on the amount of purification carried on. If storage, sedimentation and filtration are used, your magician may again be called upon, this time to produce a magic carpet and to transport the group to a sunny hillside spot for a picnic dinner, trans-

forming them en route gradually into lowly bacteria. As such, things will seem strange and unusual. For example, 25,000 sitting side by side without crowding, will be able to sit on a board or even a pencil line one-inch in length; growing up will be rapid, for maturity will be reached within 20 minutes; unsightly middle-age bulges will be conspicuously absent—indeed so thin will your hearers become
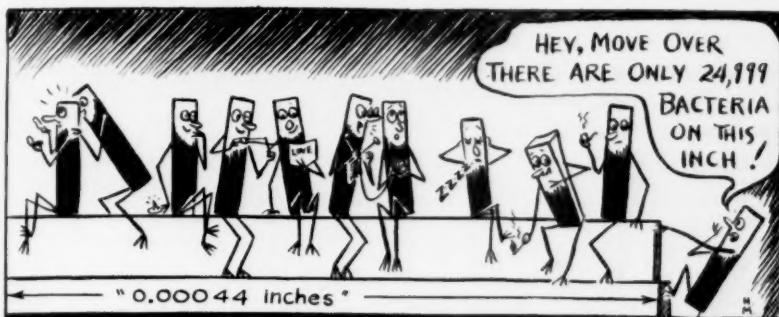
Room For One More
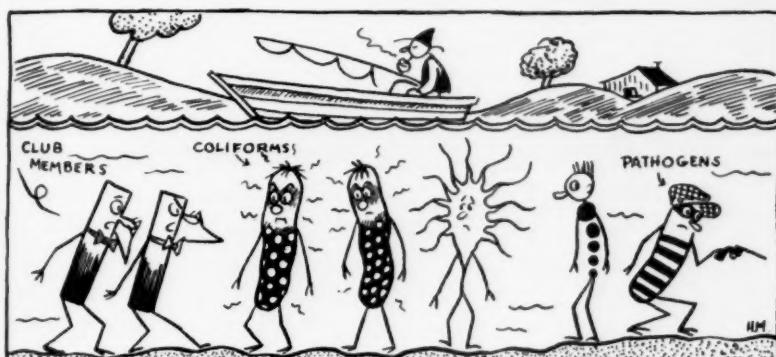
The Bacteria Club Members Meet Folk lower in Social Life

on growing up that they will actually split in two, for bacteria are "fissure" organisms and multiply by division. If we now imagine a heavy rainstorm catching them unawares, we can start their inspection trip under conditions that are actually found in nature. The "Bacteria Club Members" will be splashed and tumbled about and washed along, first into rivulets, then into brooks, and finally into sizable streams and rivers. Along the way their number will be greatly increased, and many folks, lower in the social scale, will be

encountered, even to many from "across the tracks" and such gangsters as the pathogens causing dysentery and typhoid fever. We will learn from experience that running water does not necessarily purify itself, for with every increase in volume of water and velocity, more and more pollution will be added to the stream. Suddenly the rapid bouncing journey will end in the quiet waters of the reservoir, to be the home of these Club Members, for a year (or whatever the storage period may be). All, however, is not peaceful—disturbing is the high mortality rate of both the good and harmful organisms. The natural settling out of suspended matter carried by the streams carries many of the bacteria to their graves on the reservoir's bottom. Sunlight also aids in this destruction, and this is particularly notice-

In the Quiet Waters of the Reservoir

able in the typhoid organisms, which are obviously out of their natural habitat, so much so that within seven days few survive and practically none after fourteen days. That length of storage or age of water bears no relation to "stagnant water" will also be observed, for stagnation is the result of absence of air. This was demonstrated by an exciting adventure when a strong convection current carried them far below the surface, among strange creatures living without air and therefore called anaerobes, whose manner of living resulted in a strong odor of "rotten eggs" (hydrogen sulfide), colored water, and the presence of manganese and iron.

Finally, only 20 or 30 of each 100 of the original group entering the reservoir are transported through a dark tunnel to new dangers. Here in the mixing basin of the filtration plant, every trick at their command is required to escape the clutches of the millions of fingers

clutching them from the gelatinous masses of aluminum hydroxide
flocs.   So successful is this entanglement that in the slow trip through
the plant's settling basins tons of sediment and thousands of bacteria
are removed.   The original hundred now numbers but 5 to 10 or
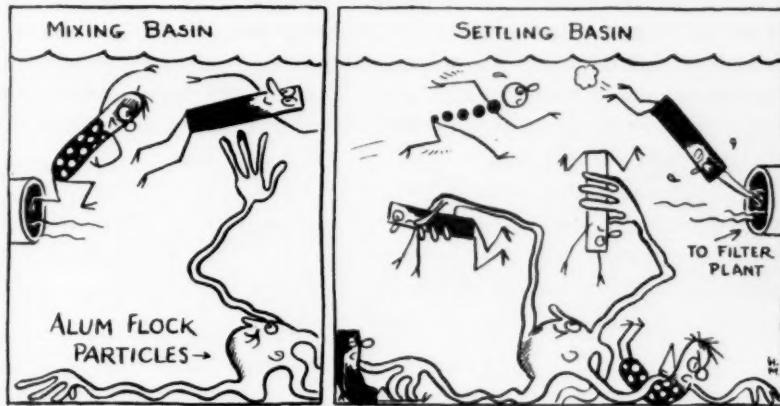
Coagulants Catch Them

Chlorine Finishes The Job

even less, and these find the graded sand filters—next item in the
purification process—an almost impassable barrier.   If by hook or
crook this barrier is hurdled, such an organism is certain to meet
instant death at the hands of another arch-enemy, chlorine—murder-
ous in even the minute dosages used.

This ends the magic journey; coming back to life, your hearers may be interested in seeing how bacteria look on an agar or E. M. B. plate and how the chlorine application is actually controlled. The residual chlorine test is one quickly performed and is a good visual example of the control of purification processes. Because chlorine is so well known and blamed for so many ills, it may be well to point out that it is continuously applied through sensitive, expensive machines and in quantities so small that all the water used by a family of four in an entire year would have had added to it but three or less ounces of chlorine.

In some such way your hearers may be conducted on a tour of your plant—this particular tour has purposely been made as non-technical as possible. All of it is probably too lengthy for the average talk, for time should be left for questions which will be sure to come if your job has been at all well done.

Applicability of Various Service Line Materials

By E. Sherman Chase

SINCE water works men first began to gather in groups and associations to talk over their problems there has probably been no subject so thoroughly discussed as that of service pipe. Discussions have covered size, rigid versus flexible connections, depth of laying, cost, proportion of cost borne by water taker, and other features, but the most violent discussions appear to have raged around the question "What materials shall be used?"

There are literally scores of references in the water works literature to discussions, investigations and reports upon the subject of proper materials for service pipes. One of the earliest papers on this topic was one by the late W. H. Richards, Superintendent of the New London, Connecticut, water supply, published in the Journal of the New England Water Works Association for 1884, only two years after that Association was first organized.* From then on hardly a year has passed without something on the subject appearing in the publications of the American or the New England Water Works associations.

The New England superintendents have been particularly inter-

* EDITOR'S NOTE: At the first Convention of the American Water Works Association, held in St. Louis, March 29-31, 1881, service line materials were discussed. The following excerpts from the record of that meeting are of interest:

> "On the relative merits of materials for services, Mr. Whitman stated that the city of Boston had thoroughly tested galvanized and enameled wrought-iron and lead, and had proved lead pipe to be the best in all particulars.
>
> "Mr. Holly quoted a case of lead poisoning and the causes thereof, which clearly proved that the case was due to negligence in not washing out the pipes. He (Mr. Holly) used enameled wrought-iron exclusively."

ested in the kind of pipe used, partly because of the quality of the New England waters. Generally these waters are soft, whether from surface sources or from the ground. Surface waters are high in dissolved oxygen and the ground waters high in carbon dioxide. These characteristics have had a marked influence upon the kind of materials favored. Another reason for the interest in the kind of service pipe is the fact that some of the earliest water supply chemists of this country were connected at one time or another with the State Board of Health of Massachusetts, whose pioneer researches in various phases of water supply problems have formed the basis for much of the water supply practice in the United States.

Requirements for Service Pipe

There are certain requirements which materials for good service pipe should meet. First, the material should not be such as:

(a) To impart to the water passing through the pipe qualities injurious to the health of the consumer;

(b) To produce deterioration in the quality of the water as regards appearance, taste or odor;

(c) To increase the hardness, iron, copper or zinc content to such an extent as to affect the water adversely for domestic or industrial uses such as laundry, dyeing, bleaching, etc.

Secondly, the material should be:

(a) Of such character as to permit the pipe to retain its carrying capacity and to maintain a clear waterway;

(b) Strong and durable under the conditions of service;

(c) Easily laid with simple tools and a minimum of skilled labor;

(d) Relatively inexpensive, taking into consideration the probable life.

Kinds of Service Pipe

Many kinds of service pipes have been used—lead, steel, wrought iron, brass, copper and cast iron. Steel and wrought iron have been used with and without lining and with and without galvanizing. The general use of copper tubing is of relatively recent origin but lead service pipes were probably the earliest commonly used in this country.

Lead has the advantage of flexibility, ease of laying and durability. It must be extra strong to stand the external and internal loads and it has the disadvantages of ease of injury, need for skilled work-

men, relatively high cost and, with certain waters, the danger of producing lead poisoning. Some water departments in New England, where danger of lead poisoning appears remote, will not use any other material.

Steel and wrought iron have the advantage of simplicity of installation, sufficient rigidity to permit jacking, fair durability and relatively low cost. Where steel and wrought iron pipes are used, they are generally galvanized to protect them from both internal and external corrosion. With soft waters they are frequently cement-lined. Even with galvanizing, except with moderately hard noncorrosive waters, steel and wrought iron pipes are subject to corrosion, clogging with iron rust and they frequently produce rust in the water passing through them.

Brass appears to be relatively little used, on account of its cost. It is strong and rigid and under some conditions satisfactory. On the other hand, it is subject to corrosion in the case of soft waters containing substantial quantities of carbon dioxide.

Copper tubing has become quite popular in recent years. It has the flexibility of lead, is relatively noncorrosive, easy to lay and not too expensive. It has the disadvantage, like brass, of being subject to corrosion with soft ground waters carrying carbon dioxide. Water carrying dissolved copper tends to produce copper stains on porcelain plumbing fixtures and on laundered goods.

Cast iron, except for the larger services, is relatively little used. It has strength and durability, but is susceptible to corrosion unless lined. It is not as easily installed as copper tubing.

Effect of the Quality of the Water

Much of the difference of opinion with respect to the proper kind of service pipe, and much of the conflicting experience with the same kind of pipe in different places, is obviously due to differences in the character of the water supplies involved. Hard waters have relatively little effect upon any kind of service pipe. Soft surface waters high in oxygen content are particularly corrosive with iron and steel pipe both with and without galvanizing. Soft ground waters high in carbon dioxide are particularly bad for lead, copper or brass pipe.

Soft waters have a tendency to dissolve some of the lime from cement-lined pipe particularly when the pipe is first laid.

In the Southwest certain soils are particularly hard on steel and iron pipes as regards external corrosion. On the other hand there

are soils of alkaline characteristics which preserve black steel pipe for many years.

Practically all metal pipes are adversely affected by stray electric currents, even those of small magnitude such as may result from the grounding of telephone and electric services on water pipes.

Another condition which may affect service pipe is the change in quality of water, brought about by change in source of supply or by the introduction of filtration. Surface waters unfiltered generally tend to form protective coatings and are usually not particularly aggressive. On the other hand, clear ground waters high in carbon dioxide, or filtered waters rendered aggressive as the result of the use of alum, affect seriously practically all kinds of pipe except those provided artificially with substantial protective coatings. Thus a change from a surface supply to a ground water supply or to a filtered supply is likely to result in service pipe difficulties. Of course the effect of this change can be counteracted to some extent by corrective treatment with alkalis.

Conclusions About Currently Available Materials

A review of the experience of the past 50 odd years leads to the following generalizations with respect to service pipe materials:

1. There is now no uniformly satisfactory material in common use.

2. Material satisfactory with one kind of water may be far from satisfactory with other kinds.

3. For hard waters, low in carbon dioxide, lead, galvanized iron and steel and copper are reasonably satisfactory.

4. For soft surface waters copper is probably the best of the materials now available.

5. For soft ground waters high in carbon dioxide cement-lined iron appears to give on the whole the best results.

6. Lead should not be used with waters high in carbon dioxide.

As is true with all generalizations, the above conclusions are subject to exceptions, but may serve as a guide to judgment in the absence of actual experience.

Service Pipe in the World of Tomorrow

After reading the mass of literature available on the subject and after listening to discussion upon discussion relating to service pipe material the writer has reached the conclusion that the World of

Tomorrow must develop a new kind of material for services. Just what this material may be he is not prepared to say, but the development in the field of plastics and synthetic resins indicates that in this direction may lie the answer to the water superintendent's prayer for the perfect service pipe. At present there are materials such as Lucite which appear to possess some characteristics not so far different from those sought for service pipes. Here lies a field for research by the chemical industry offering vast possibilities.

Legal Responsibility for Kind of Service Materials

The principal reason for this brief review of service pipe materials is the recent decision of the Massachusetts Supreme Court, paralleling decisions in England, in the matter of the responsibility of water purveyors for the quality of water delivered to their consumers. These decisions have already received considerable publicity in the technical press, but deserve to be brought to the attention of all members of this association.

Both the Massachusetts and English cases were brought as the result of lead poisoning due to the solution of lead in passing through lead service pipes before use for domestic purposes. The English decision was rendered by the Court of Appeal early in 1938 and the Massachusetts decision on January 10, 1939.

English Decision.   In the English case a man and his wife claimed damages for personal injuries arising from the alleged breach of statutory duty by the Irwell Valley Water Board. The plaintiffs claimed that they had contracted lead poisoning from the water supplied by the Board. The Board's defense was that the water was pure up to the stop cock and that there had been no evidence to show that the water was dangerous in itself at that point.

The Commissioner who heard the case in the lower court found that the defendants had satisfied their statutory duty, but that this did not end matters. He found that the Water Board had a common law duty above that imposed by the statute. The Board knew that the plaintiffs intended to use the water for domestic purposes and that there was a high degree of probability that the water would be conducted through lead or tin-lined pipes. Consequently the Water Board should have warned the customers to take precautions either by putting in a different kind of pipe or by drawing off a substantial amount of water before using. The evidence indicated that the plaintiffs had received no warning of any kind and the Commis-

sioner held the opinion that the defendants were guilty of an act of negligence. Judgment was entered for the plaintiffs to the amount of about $4,000.

The Water Board appealed to the Court of Appeals, but the Court dismissed the appeal without calling on counsel for the plaintiffs. Lord Justice Greer giving the judgment stated that the Water Board had been warned over and over again that the water passing through lead pipes was liable to be contaminated before reaching the consumer, and that there was a duty on the part of the Board to supply water in such a condition that, when used, after going through lead pipes, it would be reasonably fit for domestic use.

Apparently this English case establishes precedent in England, because in the report of the decision it is stated that the Court had to consider, perhaps for the first time, whether there was more than a statutory duty incumbent upon the Board to exercise reasonable care that when the water reached the consumers it was reasonably fit to use. The Lord Justice said that there were means which might have been adopted to protect the water users: one, to adopt measures to reduce the plumbosolvency of the water; and the other, to circularize consumers, warning them to draw off water before using it for drinking purposes.

The judgment read in part as follows:

"The evidence is conclusive that if there was such a duty the board did not perform it. It delayed a very long time in installing apparatus which would render the water harmless. It did not adopt the simpler method of warning consumers, and it is no protection for the board to say that it was advised by the local authority that it might be dangerous to frighten people by sending out a warning notice.

"From 1929 to 1935 a series of complaints had been made by water consumers that they were ill with lead poisoning. A long waiting period took place, in which no steps were taken to protect the unfortunate people who were drinking this lead contaminated water. I find it impossible to come to any other conclusion than that the board, through its agents, was negligent.

"It would be lamentable if there were no remedy for the plaintiffs in these circumstances; the law of England would be very deficient in protecting the rights of water consumers."

Massachusetts Decision. The Massachusetts case relates to action brought by Earle R. Horton against the town of North Attleboro,

tried in 1937, with a decision in favor of the defendant.   On appeal, to the State Supreme Court, on exceptions to the trial judge's rulings, the exceptions were sustained.

The plaintiff, Horton, applied for a supply of water at his house in 1933.   The plumber installed a $\frac{3}{4}$-inch lead service pipe from the property line to the meter, a distance of 145 feet.   The town connected the service pipe to the street main by means of 27 ft. of lead pipe, making a lead pipe service connection of 172 ft. in length. The regulations of the Water Board provide that service pipes must be inspected by the Department and that the installation thereof must be made under the direction and with the approval of the Super-intendent of Water Works.   The use of lead pipe has been almost universal in connection with the North Attleboro system.

Up to the time of the use by him of the water supplied through this lead service connection the plaintiff's health had been good, but thereafter it began to fail.   In the following summer his trouble was diagnosed as "lead poisoning" and the evidence showed that it had been caused by the drinking water.   Four parts of lead per million were found in samples of water which had stood in the pipe for 3 hours, as compared with $1\frac{1}{2}$ to $2\frac{1}{4}$ p.p.m. in water that flowed freely through the pipes.   As much as 8 p.p.m. of lead were found in water that had stood in the pipe over night.   Furthermore, the water contained 30 p.p.m. of carbon dioxide.

Action was brought against the town in October, 1934, on two counts.   The first count claimed a warranty that the water would be fit for drinking after passing through the lead pipes, and the second count claimed negligence on the part of the town.   The jury returned a verdict for the defendant on both counts.   Excep-tions were taken by the plaintiff to certain instructions and refusals to instruct on the part of the trial judge and on these exceptions the case was carried to the higher court.

The trial judge instructed the jury that the water was sold and delivered at the property line and that the defendant was not liable if the water was fit for human consumption at that point, even though it became unfit after passing that point, but if the water was unfit at the property line the defendant would be liable only for the injury caused to the paintiff by the lead that was in the water at that point.   This ruling was excepted to by the plaintiff, as was the judge's refusal to instruct the jury as follows: "1. The defendant in supplying water for domestic use impliedly warranted that it was fit therefor when consumed through pipes of a kind approved by

the defendant's authorized representative. 2. When the defendant required that water which is sold for drinking purposes be conducted through pipe of iron, tin or lead, it expressed to the plaintiff its approval of lead pipe."

Decision of Massachusetts Supreme Court

The trial judge ruled, without objection or exception from either party, that the town was bound by an implied warranty under the Massachusetts sales act (Gen. Laws, Tercentenary Edit. Chap. 106, par. 17 (1)). The decision of the Supreme Court, prepared by Judge Lummus, however, stated: "It could readily be found if not ruled on the undisputed facts, that the plaintiff made known to the defendant that the water was to be used for purposes which included drinking, and that the plaintiff relied on the defendant's skill to furnish him pure water. But the weight of authority is to the effect that that provision of the sales act does not apply to the furnishing of a supply of water through pipes."

Judge Lummus stated, however, that this was not a question for them to decide in this case, because the basic ruling of the lower court judge, made without objection or exception, had become the law of the trial and that the exceptions to be considered were based upon the assumption that the basic ruling of the lower court was correct. The Supreme Court, after considering the purpose for which the water was furnished, ruled, "If there is a warranty under the circumstances of this case, as the trial judge ruled, it is a warranty that when water becomes the property of the plaintiff it will be reasonably fit to conduct through one hundred and forty-five feet of lead pipe into the house and then to be drunk." Consequently the court sustained the plaintiff's exceptions on the first count.

On the count for negligence the trial judge instructed the jury that the plaintiff must show the unfitness of the water for human consumption as delivered at the property line, and that this unfitness was due to negligence on the part of the town. The plaintiff excepted to the first part of this instruction and to the refusal of the judge to instruct the jury that "A town proferring to sell water for domestic consumption is under a duty to take such reasonable steps in the then state of common knowledge of those versed in the subject, as may reasonably be expected to disclose whether the water is adapted for such use when transmitted through the kind of pipe which the town expects will be used."

Judge Lummus stated that, "the defendant owed the duty of

furnishing at all times a supply of wholesome water so far as that could be done by the exercise of care, diligence and skill, which is ordinary and reasonable in view of the nature of the business." The court, therefore, found the trial judge in error in instructing the jury that the responsibility of the town stopped at the water gate and that the instruction requested by the plaintiff was correct in law and should have been given in effect. The court stated "The defendant was bound to take into consideration the fact that the water could not be drunk at the water gate, and to adapt its care to the fact that its water had to pass through a leaden service pipe to the house before it would be or could be used for drinking." In view of this finding the exceptions of the plaintiff on the second count were sustained.

So far as the writer knows there has been no previous Supreme Court decision in Massachusetts which places the responsibility for the quality of a public water supply squarely upon the seller thereof. Damages for typhoid fever caused by impure supplies have been obtained in other states, but apparently no such cases have been brought in this state. Furthermore, the ruling in the Horton vs. North Attleboro case establishes responsibility for quality of water on the seller thereof, even after the water has left its property.

The question also arises as to what the courts might rule in the case of qualities, which although not harmful to health, might produce damage to equipment, such as hot water boilers or damage to material being processed, such as laundry work. Furthermore, there is the possibility of an industry, depending upon the satisfactory physical and chemical qualities of a public supply, being damaged as the result of changes in these qualities, such as an undue increase in iron content.

Obviously, water departments and water companies are being held more and more accountable for the quality of the water they deliver for use and standards of quality are becoming more rigorous and for this reason the utmost care should be used in selecting the kind of service pipe with particular regard to the characteristics of the water supply and the conditions of service.

Service Materials

By Paul D. Cook

THE subject of service materials is rather comprehensive when one considers the various methods of installation, the wide variety of soil conditions, the difference between aggressive and non-aggressive waters, and other pertinent factors. Service pipes form the major share of the investment in the service connection and I shall confine my remarks to them.

The most universally accepted and used service pipe materials are copper, red brass, yellow brass, lead, cast iron, wrought iron, steel and various alloys. Several of these are classified into various wall thicknesses, weights, content of base metal, etc., so one must consider a variety of materials, no one of which, in my opinion, is a panacea for all geological, chemical, physical and economic conditions with which water works men are faced.

We who receive our water supplies from Lake Erie are fortunate in obtaining a relatively non-aggressive water. This condition does not obtain, however, in some parts of the state where it is necessary to treat the water to lessen its corrosive action.

Soil conditions are also an important factor in determining the most economical installation. For example, in Lake County we have two decidedly different soil conditions—in one locality the clay soil makes galvanized wrought iron or steel undesirable from an economic standpoint, while in another section the same pipe after 15 years of service in sandy loam is still in good serviceable condition. Due to this fact and a variation of soil conditions at other points in the county, in 1929 we adopted Type K copper tubing for general use. All new services and replacements since that time have been of that material.

It has been determined that red brass pipe which contains 85 per cent copper and 15 per cent zinc withstands corrosive action substantially better than does straight copper, it appearing that this composition represents the ideal mixture in this respect.

Advantages of Copper Tubing

Yellow brass, containing from 60 to 67 per cent copper and the balance zinc, has proven disappointing for water service on account of rapid dezincification and resultant failure of the pipe walls. In the cheaper grades containing less copper this process is more pronounced. Some advantages which Type K copper tubing has over red brass, if water and soil are not extremely aggressive, are convenient transportation in coils, longer lengths, malleability, ability to expand without breakage when frozen, and natural provision for longitudinal expansion and contraction, soil movement or main travel resulting from laying the pipe in a wavy line.

Lead and Copper in the Human System

Lead pipe has some similar advantages but careful investigation should be made by a competent chemist as to the probability of small amounts of lead being carried into solution and to the human body. It has been definitely established that lead entering the human system is cumulative and ultimately may be detrimental to health, while medical authorities seem to be in agreement that copper in quantities obtainable in waters, acceptable from the standpoint of palatability, do not harm the consumer. In fact, Robert Spurr Weston, Consulting Engineer of Boston, states that certain amounts of copper have been proven an essential element in food or drink, rather than the reverse. On the other hand, nothing good can be said of lead in any amount.

Corrective water treatment can be resorted to in case the water is found to attack lead.

So far as zinc from galvanized pipe or brass pipe is concerned, it appears to be unimportant as a health menace.

Care should be taken insofar as possible to avoid the use of dissimilar metals in the service line. The difference in potential results in deterioration of the weaker metal. For this reason, if a galvanized line with a lead gooseneck is being repaired or replaced with copper, the lead gooseneck should be removed and copper carried to the corporation stop.

Durability of cast iron is, of course, well known to all of us. It is

not manufactured in sizes small enough for the average water service
but is highly recommended for sizes of pipe within its scope of manu-
facture.

It appears to me that it would not be feasible to make any general
recommendation as to the best material to use under all circum-
stances but rather to urge the engineer or superintendent to acquaint
himself thoroughly with local conditions and then make his selection
with those conditions in mind. Service connections, if constructed
to meet local soil and water conditions and installed under strict
supervision within the bounds of reasonable economic considerations,
should leave the department free from trouble of this kind.

Design and Maintenance of Earth Dams

By William P. Creager

THIS paper is intended to describe primarily the basic principles involved in the maintenance of earth dams. However, the executives and operators to whom such maintenance is intrusted, must be conversant with the underlying principles of design in order to guard against, interpret properly, and correct efficiently the misbehavior of any part of the structure. For this reason the paper will cover also the basic principles of design, at least to the extent necessary to describe the destructive forces acting on earth dams and the general provisions in the design and appurtenances provided to control them.

With this information in mind, the operator will be in a better position to know just what steps to take should any feature of the structure prove inadequate. Unfortunately, to make a complete story, it will be necessary to review some principles which may be considered rather elementary to many. However, these will be passed over as quickly as possible.

The first impression the writer desires to convey to you is that earth dams, properly designed and constructed, are safe structures, adequately adapted to the use to which they are put. However, in common with other types of important engineering works, earth dams have been known to have defects, ranging from minor faults to complete failure.

In the following discussion, the writer will call attention to many possible defects in earth dams of varying degrees of importance. To line up these defects for simultaneous review gives a rather pessimistic color to earth dams and it is necessary therefore to state at the start that, in most cases, practically no defects of any nature appear and that the history of earth dams discloses that the percentage of serious defects is negligible.

However, in spite of the good record which dams of this type have,

WATER SURFACE

FLOW LINES

ROCK SURFACE

PHREATIC LINE

SUSPENDED EGRESS

h

FLOW LINES
FIG. 1 (a)

WATER SURFACE

PHREATIC LINE

LINES OF EQUAL PORE PRESSURE

0
10
20
30
40
50
60

PRESSURE LINES.
FIG. 1 (b)

WATER SURFACE

A
B

PHREATIC LINE.

SLIDING PLANE

D   C

PLANE PRESSURES
FIG. 1 (c)

WATER SURFACE

A
E

PHREATIC LINE

SLIDING PLANE

B   C

D

FIG. 1 (d)
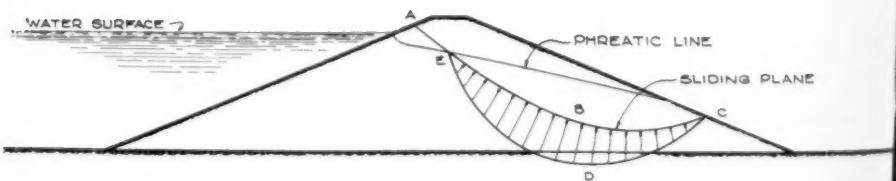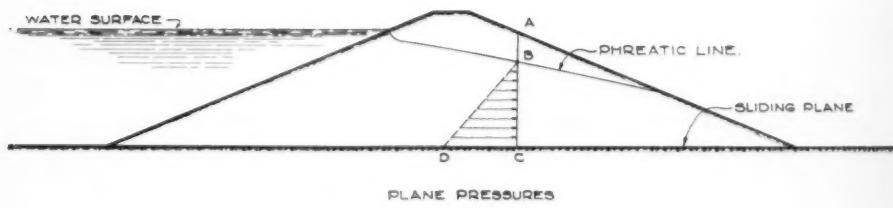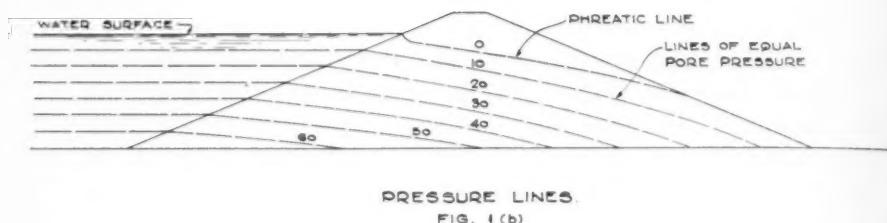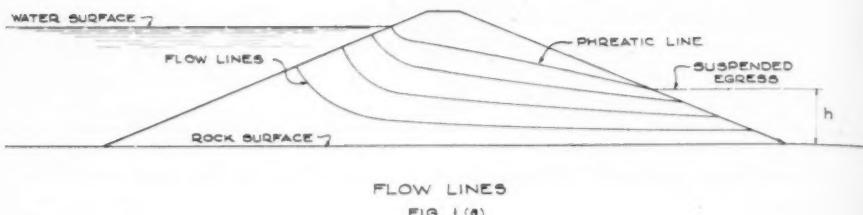
sight cannot be lost of the fact that the sudden release of large volumes of water is one of the most destructive agencies known to mankind. Therefore, conscientious vigilance on the part of operators, particularly when such dams are new, is a duty which should be taken very seriously.

The sciences of soil mechanics and hydrology, the principal factors in the design of earth dams, have made enormous strides in the last decade, resulting in great improvement in the safety and adequacy of such structures. However, nature seldom lays down homogeneous geologic deposits. Variations are great in some cases. It is not possible to sample every part of the foundation and borrow pits. Therefore, unless the boundaries of relatively poor materials are very definitely known, it is necessary to assume that the entire structure and foundation are composed of the worst material which has been encountered. Explorations must be made to an extent sufficient to indicate that the foregoing assumption is well on the safe side.

For this reason there is a factor of safety in most dams in addition to that assumed in the analytical design. It is believed that serious defects in earth dams may be attributed to causes which cast reflection on the designers and constructors rather than on the type of structure or the theories of design. In some cases, adequate inspection and maintenance would have prevented troubles incident to such defects.

Seepage Forces

Figure 1(a) shows, more or less diagrammatically, the flow lines, or direction of seepage for the simple case of a homogeneous dam on impervious foundation without drains. The topmost flow line, known as the "phreatic line," is the upper limit of saturation by free water. Capillary water lies above the phreatic line but exerts no hydrostatic force on the dam.

It will be noted that, for this case, the phreatic line intersects the downstream face of the dam. Hence water seeps out of that face which, as explained later, is an objectionable feature. The vertical distance, h, between the foundation and the point at which the phreatic line intersects the face of the dam is known as the height of "suspended egress."

Figure 1(b) shows, for the same type of dam, lines of equal hydrostatic pressure or "pore pressure" in feet of water. The pore pressure is always zero at the phreatic line and increases at lower elevations.

These lines of equal pressure can be determined analytically for simple cases but are usually obtained by electric analogy or model experiments.

The total pressures on any line drawn in any direction through the dam, as lines ABC in figs. 1(c) and 1(d) can be obtained from the lines of equal pore pressure shown in fig. 1(b).

Should the dam rest on a foundation of slippery material, any part downstream from any line as ABC in fig. 1(c) may slide on the plane CE due to the pressure of the pore water BDC on the plane BC. This pressure is resisted by the shearing strength of the plane CE.

The dam must also be tested for possible sloughing, as on the plane ABC in fig. 1(d). The resultant force obtained by combining the pore pressure EDC with the total weight of soil and water above ABC is the force tending to cause the slide, and the resistance is the shearing strength of the plane ABC.

Several planes of possible rupture, such as ABC, usually drawn as circles for convenience, are tested in order to determine the most likely line on which sloughing might occur. This is known as the "most dangerous circle" or "Swedish geotechnical" test. For dams on earth the most dangerous circle ABC may extend into the foundation.

It is quite evident, from the foregoing description, that the forces acting on the dam can be greatly reduced and the safety greatly increased by lowering the elevation of the phreatic line. The designer therefore aims, by correct distribution of the available materials and by the use of certain appurtenances, to accomplish this.

General Features of Design

Figure 2 shows the same dam as in fig. 1(a), but with the available material arranged so as to have the least pervious, or tightest, material in the center and the most pervious on the outside. This arrangement results in a considerable lowering of the elevation of the phreatic line and a reduction of the height of suspended egress.

Figure 3 shows the same arrangement but with a drain added at the toe of the dam. The conditions are still better. The suspended egress has disappeared but the phreatic line is still uncomfortably close to the downstream face. In old dams, drains, if used at all, were usually placed at the toe as here indicated.

Figure 4 shows the more modern method of locating the drain well within the interior of the dam. The phreatic line is now much lower.
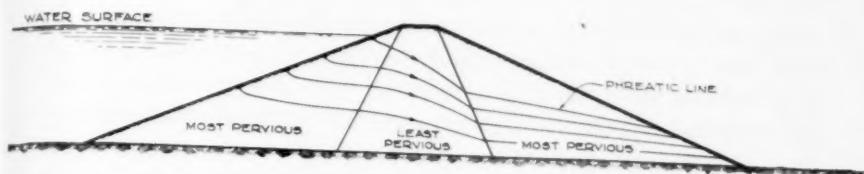
FIG. 2
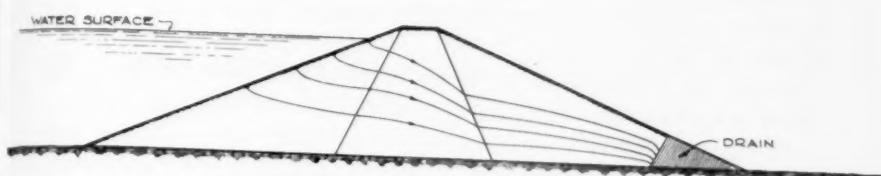
FIG. 3
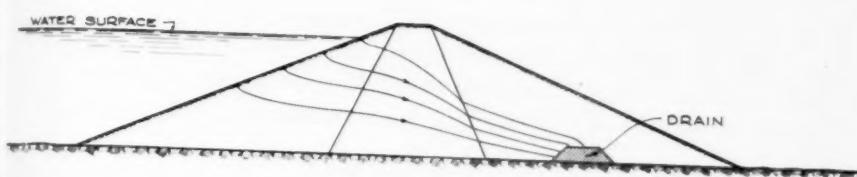
FIG. 4
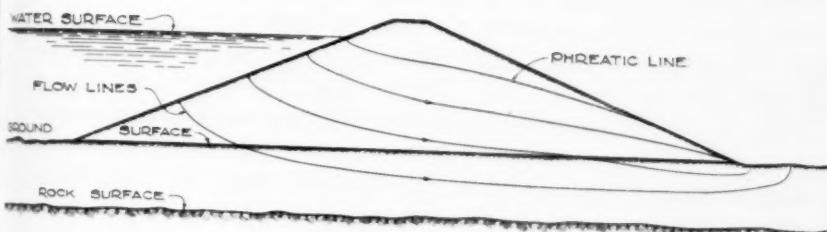
FIG. 5
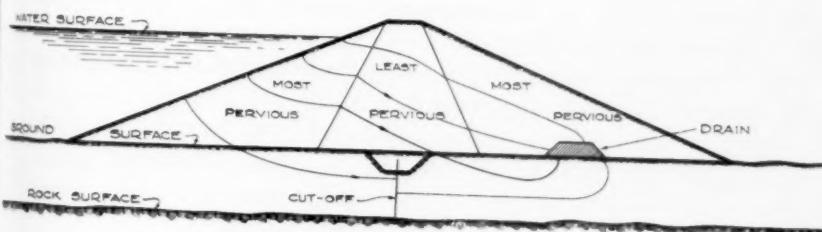
FIG. 6.

Figure 5 shows an earth dam on an earth foundation. It indicates how, without the provisions above mentioned, the seepage flow not only reaches the downstream face but also rises vertically to the surface below the dam. Thus we have the danger of both sloughing and vertical piping described later. If the foundation is quite pervious with respect to the dam, the suspended egress in fig. 5 might be very small with no appreciable amount of water seeping from the downstream face but a considerable amount rising to the surface below the dam.

We will pass over the intermediate steps and show, in fig. 6, the effect of correct distribution of materials and interior drains.

If the foundation is relatively quite pervious but overlies impervious material at not too great a depth, the relatively impervious core or some other type of cutoff is carried to the impervious material.

The foregoing are the general features of earth dams. Of course, there are many variations including an upstream blanket in lieu of a cutoff to impervious foundation and zones of rock fill for the pervious outer portions. Concrete core walls are seldom used in modern dams unless the materials available for construction are very pervious.

Drains

Drains are not only one of the most useful appurtenances of earth dams but they are used very frequently for temporary and permanent control of unruly seepage water after the dam is put into service. Consequently it is necessary to describe their action in considerable detail.

The ordinary type of drain consists of either a coarse rock-fill or an open jointed or perforated pipe surrounded by coarse gravel or crushed stone. To prevent clogging of the drain by material being washed into it, the drain is surrounded by a filter. If the drain consists of a coarse rock fill, the surface interstices are chinked with spalls and a layer of coarse gravel is placed against it. Then, against the gravel, are located successively several layers of sand, each having grains smaller than the preceding layer until the last layer next to the dam or the foundation is only slightly coarser than the material in the dam or foundation.

Each layer has a large percentage of grains which are only slightly larger than the voids in the adjacent layer of next larger grains. When the filter goes into operation, seepage moves a certain amount of fine materials but it soon reaches a stable condition.

Not more than two or three layers are used for the ordinary filter. As a matter of fact, a single layer of filter material would be sufficient if it were composed of a well graded mixture of very coarse to fine materials. However, there would be a considerable movement of fine materials before the filter became stable and the drain proper would have to contain a sufficient amount of voids to receive without clogging the material which has been thus moved.

Therefore, if the drain has a free exit so that the moved material will be washed away readily and will not tend to clog, the use of gravel, well graded from coarse to fine is permissible, particularly for remedial measures to correct "piping" or sloughing as explained later.

Drains in dams, if properly proportioned and carefully built, are thoroughly reliable and are given full credit for performance in the design of slopes. However, if they, for some reason, should not be adequate, the phreatic line will be higher and the dam will not be as stable as anticipated. For this reason piezometers or hydrostatic pressure gages are sometimes installed in earth dams to indicate the elevation of the phreatic line.

Amount of Seepage

No earth dam is absolutely tight. Even those below which no flow is in evidence are losing water into the foundation or by evaporation from the face of the dam or the foundation. Excessive seepage, if properly controlled is not dangerous. The writer has known cases where water has been seeping safely for years through earth dams at the rate of over ten gallons per minute per foot of length of dam.

However, it is obviously desirable to limit the amount of seepage to whatever amount is considered economical and then to take care of the resulting flow safely by adequate drains. Of course, it is obvious that, if anything goes wrong, it can be remedied more quickly and at less expense if the flow is small.

All of the provisions mentioned heretofore for lowering the phreatic line, except the drains, affect a reduction in the amount of seepage. Drains shorten the length of the path of percolation and increase the amount of seepage and hence interior drains result in greater seepage than drains at the toe of the dam. This is why there were some objections to the modern use of interior drains.

However, the amount of loss by seepage is usually very small and, although the modern method of locating the drains in the interior of the dam requires that they be slightly larger to accommodate the larger flow, the great advantage gained in lowering the phreatic line more than compensates for the increased expense.

All dams tighten with time due to deposits in the reservoir. In some cases the change is very rapid if floods muddy the water. In others the seepage will remain nearly constant for years.
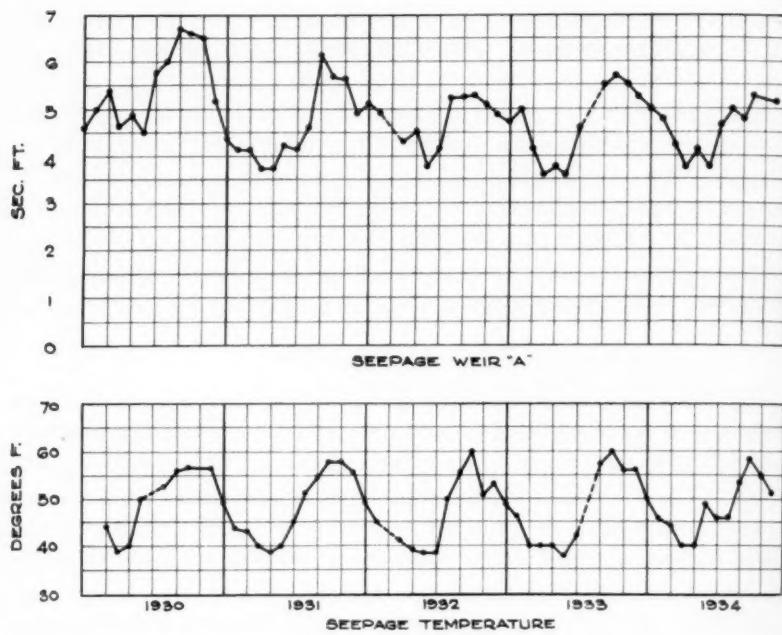
FIG. 7

Excessive seepage is costly to reduce after the dam is put into operation although it has been accomplished in small reservoirs by placing a thin blanket of bentonite or other very tight material on the upstream face and on the bottom of the reservoir.

Seasonal changes in discharge, due solely to temperature variations, are to be expected. Figure 7 shows the seasonal variations in seepage from the 120-foot Soft Maple dam on the Beaver River in New York State. Changes of the magnitude of 50 per cent were caused by differences in temperature.

Velocity of Seepage

The only objection to concentrated or high velocity of seepage is at the exit of seepage to the surface of the dam or foundation and to the drains. The former being allied to the phenomenon of piping, mentioned later, and the latter requiring greater care and expense in the construction of the drains.

High velocity of seepage, well within the dam or the foundation, has never, to the writer's knowledge, given trouble. It would not be objectionable except in the remote contingency that there occurred a layer or lens of very coarse material into which adjacent very fine material could wash.

Piping

Piping is a general term used to describe the removal of soil from the dam, the abutments, or the foundation by the action of uncontrolled seepage or leakage as it emerges to the surface. Seepage tends to concentrate to the most pervious path and appear at isolated spots in the form of boils instead of over a general area. It is manifested in nature by springs. If the pressure of the flowing water is sufficient to scour the soil, piping ensues.

If the outlet of an active pipe is on horizontal ground, it takes the form of a crater. If on sloping ground it takes the form of a débris cone, the same in miniature as those in the canyon mouths of débris-laden western streams.

Where there is sufficient cohesion in the soil to prevent it from caving, a hole or "pipe" may form and continue indefinitely towards head-water. Lacking sufficient cohesion, the pipe will not form but, as the material is carried away, there will be a general settlement of the surrounding ground. A pipe may start to form and later cave. If the pipe has extended under the dam and caves, there usually results a sloughing in the face of the dam. Pipes have been known to continue to head-water resulting in the destruction of the dam. Points of egress of seepage causing piping may be several thousand feet from the dam where conditions are unusual.

Piping due to seepage occurs most frequently in medium to coarse soil. It may also occur in very fine soil but the velocity is so slow that the movement is not rapid.

There are two general types of piping; vertical piping, where the seepage rises vertically to the surface, and horizontal piping, where the seepage emerges horizontally on a slope.

Vertical piping will occur when the pressure of the seeping water at any point below the surface is greater than total weight of soil and water above that point.   Since the saturated weight of soil is about twice that of water, vertical piping will occur when the pressure at any point below the surface in feet of water is greater than about twice the depth of the point below the surface.

The factor of safety against vertical piping is shown in fig. 8 for a very impervious dam on a pervious foundation without drains.   It
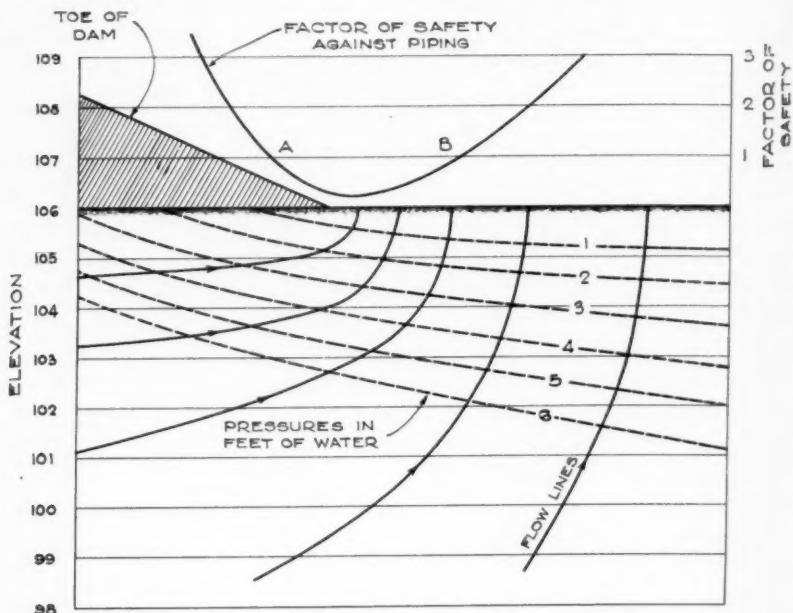
FIG. 8

is seen that, for this poorly designed case, the danger of piping is in the vicinity of the toe of the dam, the factor of safety being less than unity between points A and B.

Another case of danger from vertical piping is where there is a horizontal pervious stratum in the foundation underlying tight material on the surface.   If the accumulation of seepage water in the pervious stratum is not relieved by a drain through the tight surface material, pressure may be built up to an extent sufficient to punch through to the surface at any place below the dam.   The drain

mentioned above is a necessary appurtenance in such cases and, if omitted, there may be trouble.

The use of relatively impervious material in the central part of dams, cutoffs to impervious foundation material and upstream blankets, previously described, all effect a reduction in seepage and hence reduce the probability of piping. At the same time, the addition of adequate drains, to intercept and carry away safely any water that does come through the dam, obviates any possibility of piping in well designed structures.

If the piping is due to a concentrated leakage at some weak point in the structure, as for instance a leaky pressure pipe, leakage around or under the cutoff or through a rock abutment, the natural remedy is to plug the leak. Grouting rock abutments is common practice. Grouting leaks in earth is extremely difficult although it has been accomplished (1). Little has been accomplished with regard to grouting the pores in earth except by the chemical method which is very expensive. However, experiments on grouting of soil with bentonite are now being conducted at the U. S. Experiment Station, Vicksburg, Mississippi.

If the piping is being caused by concentration of uncontrolled seepage the only recourse is to take care of it at the outlet.

The remedy for vertical piping is to deposit sufficient weight of well draining gravel, preferably varying from very coarse stones down to fine particles which match approximately the natural material at the surface, in order to form a filter drain, as described in the foregoing pages, to balance the upward seepage forces. In some cases, the amount necessary to place is surprisingly small.

As a temporary expedient, a coffer of sand bags may be built around the piping area and allowed to fill with water (2). The total weight of water above any point in the foundation to balance the internal water pressures is thus increased and piping will be stopped if the depth of added water is sufficient.

In the case of vertical piping due to a horizontal under-stratum of pervious material, as previously described, the installation of a drain through the top impervious layer is a remedy. In some cases the driving of well points to the pervious stratum may effect a cure, although pumping of such well points may be necessary to dry the ground up sufficiently to excavate for an adequate permanent drain.

Horizontal piping takes the form of a hole, usually the size of a pencil when first observed, through which seepage water is flowing

freely. It occurs more frequently in the undisturbed material of earth abutments. Figure 9 shows a case of horizontal piping in formation. As the hole becomes larger and the piping progresses, the sloping bottom remains at a constant or slightly increasing grade and the top remains approximately level but continually rises due to sections dropping from the roof and being washed out along the bottom to the mouth of the pipe and being deposited in a fan-shaped cone below the mouth. The shape of the pipe apparently remains constant as shown in the figure but gradually enlarges.

The writer's first case of serious horizontal piping occurred many years ago in the abutment of a 120-foot dam under his jurisdiction. Due to the failure of an upper dam at the time this dam was just completed, it filled within 12 hours. The hole progressed until, within a day or two, it was 6 feet in diameter at the outlet. The
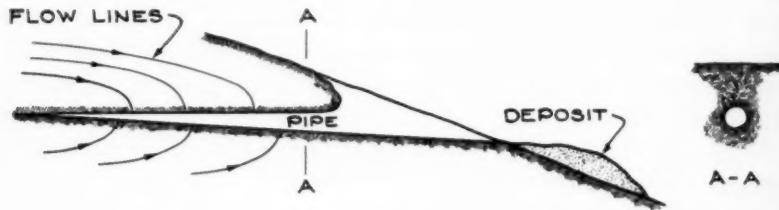
FIG. 9

distance it had progressed towards the reservoir was indeterminate as there was a bend in it and, of course, no one dared explore it.

Before remedial measures could be taken, the roof of the pipe caved in completely. Fortunately there was enough coarse material in the abutment so that a filter drain was formed automatically and shortly the discharge was flowing clear and no further trouble has been experienced.

The writer recited this experience at the meeting of the International Conference on Soil Mechanics and Foundation Engineering at Harvard in 1936. The story was matched by another member who told of a case of vertical piping below a concrete dam on earth foundation. This piping continued until it reached the reservoir. A barge was floated out with the intention of sinking it to plug the hole through which water was passing under the dam. However, the barge up-ended, dived under the dam and bobbed up in the lower river.

Horizontal piping is prevented by providing an ample length of path of percolation in the abutment, around any cutoffs which have been provided and to arrange sufficient drains to attract seepage before it can carry through to the downstream side.

The remedy for horizontal piping should be applied as quickly as possible to avoid expense as well as danger. The opening at the mouth of the pipe should be enlarged as much as feasible and filled with well draining gravel, preferably varying from very coarse stones down to fine particles which match approximately the material surrounding the pipe, in order to provide a filter drain as described in the foregoing pages. The outside could be merged into a rock fill if expedient.

At the same time, well points, to act as piezometers, should be driven through the original surface to the pipe at several places above the new fill in order to observe the pressures to which the new fill will be subjected, that is the elevation to which the final phreatic line will adjust itself.

A special case of piping is where seepage finds an easy path along conduits or abutment walls. Insufficient compaction of the soil against the concrete, settlement away from objectionable overhanging concrete, or rock abutments may be the cause. Fins on abutments and collars on conduits are added to prevent straight line flow, should a pipe work back, but these are not always effective.

If the conduit is under pressure, piping may be caused by a conduit leak, usually caused by unequal settlement, within the dam. For this reason pressure conduits are seldom used through earth dams.

Figure 10 shows the results of a break in the pressure conduit at the 140-foot Greenville dam on the South Saluda River, S. C. (3), which occurred too suddenly for remedial measures to be taken. The resulting slide is shown here principally to indicate the punishment which some dams can take. The reservoir was almost full at the time and was not lost.

Stability of Slopes

The slopes of the faces of earth dams to conform to the requirements of stability are governed by two principal considerations:

    (a) Stability in themselves as affected by seepage forces.

    (b) Stability of the foundation which is controlled by the width of the base of the dam.

Affecting stability in themselves, it will be noted that, for full

reservoir, as in the foregoing figures, the flow in the upstream half of the dam is directed towards the center line.   Thus, for full reservoir, the forces of seeping water assist the stability of the upstream slope.

On the other hand, in the downstream half of the dam, the flow is directed away from the center line and the forces of seeping water must be resisted by the strength of the downstream slopes as explained heretofore.

Fig. 10. Blowout and slump in earth dam at Greenville, S. C., May, 1928

However, fig. 11 shows how, when the reservoir is drawn down suddenly, the direction of flow in the upstream half of the dam reverses and, instead of being directed towards the center line, as in the case of full reservoir, is directed away from the center line.   Thus, for sudden considerable drawdown, the forces of seepage are against stability of the upstream slope.

It will be noted that, for the case of sudden draft, the phreatic line is very much closer to the upstream face than the downstream face, it having also a high suspended egress.

For extremely rapid drawdown, as in flood control reservoirs, the the duty on the upstream slope is usually greater than on the downstream slope, requiring flatter slopes for the former.

Fortunately, for power and storage dams, very rapid drawdown usually is not necessary and is frequently impossible on account of limited outlet capacity and the worst possible conditions are not necessarily assumed in the design of the slopes. Operators should be given definite instructions regarding the maximum permissible rate of drawdown for cases where the slopes have not been designed for the maximum possible rate of draft. These conditions are particularly frequent in canal embankments.

Sloughs or slides in the faces of dams are of the same nature and from the same cause as those frequently observed in natural hillsides. Seepage does not necessarily have to appear on the downstream face
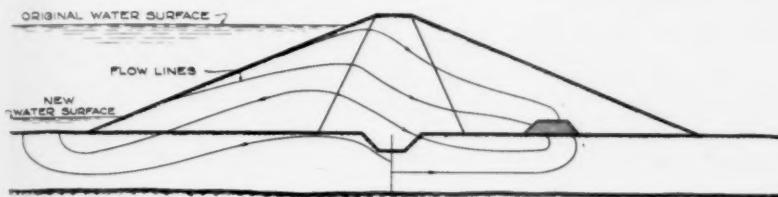
FIG. 11

of a dam for a slide to occur, if the elevations of the phreatic line are too high in relation to the strength of the slope. On the other hand, a small amount of saturation at the foot of a slope does not necessarily indicate a generally weak slope if the material is of a stable nature.

Figure 12 shows a typical small slide due to saturation of the downstream face of a dam after filling the reservoir.

For cases of impending sloughing of the downstream face in large masses, there is little that can be done immediately except to draw down the reservoir. For small sloughing and where water is issuing from the face of the dam in amounts sufficient to cause raveling of the surface, there are two expedients.

First, all water should be collected and conducted by pipes, troughs or paved gutters to the base of the dam.

Second, a horizontal trench should be dug normal to and into the face of the dam at foundation level as far as expedient and filled with well graded gravel, exactly as described in the foregoing pages, for correcting horizontal piping. This will lower the phreatic line. The

trench may have to be sheeted on each side. Pumped well points may be advantageous in lowering the water temporarily until the trench can be dug. Piezometers, installed in the slope, will indicate, by changes in the elevation of the phreatic line, the efficacy of the remedial measures which have been taken.

FIG. 12. Small slide due to saturation of downstream face after filling reservoir

Foundations

Inadequate soft foundations fail by plastic flow. Figure 13 shows a typical failure of this kind, being similar to that which occurred in 1938 at the Marshall Creek dam in Kansas. Such a failure is characterized by a sinking of the upper part of the dam (not necessarily the very top) and a bulging or lifting of the lower slope and the foundation adjacent to the dam.

Foundation failures may not be a plastic flow but may be part of a general slide along a plane such as ABC of fig. 1(d) if the plane is deep enough to intersect the foundation as mentioned under "Seepage Forces" earlier in this paper.

It is sometimes very difficult to tell, without subsurface investigations, the difference between a large slide in the dam proper and a

plastic foundation flow, as the final result of a slide ABC of fig. 1(d) would be very similar in appearance to the result of foundation failure shown in fig. 13.

The stress tending to cause a foundation failure, whether by plastic flow or a deep slide, decreases as the width of the base of the dam increases.   Therefore, in some cases, the requirements of an adequate foundation strength dictate the width of base and hence the slopes of the dam.

The seepage forces, under the condition of full reservoir, decrease the stresses in the foundation under the upstream portion of the dam but increase the stresses downstream.   The reverse is true, of course, for the condition of rapid drawdown which greatly increases the stresses in the upstream portion of the dam and the foundation.

FOUNDATION FAILURE
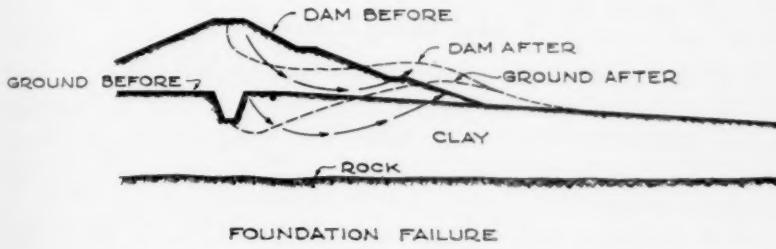
FIG. 13

The remedy for impending foundation failures of this type is to load the lower slope and the foundation adjacent to the dam where it tends to lift or bulge.   However, frequently time is not available to do this unless signs of movement have been noticed at early stages.

Warning of Earth Movement

Sloughing of the face of dams and foundation failures sometimes occur without warning, but very frequently there is some very slight incipient movement or opening of cracks which may occur several days prior to the major movement.   Unfortunately, such warning is not always observed by those to whom it has any significant meaning.

In the case of the slides on the Tappan dam on the Muskingum River, Ohio, the Fort Peck dam on the Missouri River, Montana, and the Marshall Creek dam on Marshall Creek, Kansas, warnings in the form of slight movements are said to have been apparent for several days prior to the major slide.

Permissible Saturation in Dams

The mere presence of moisture in the foundation and for a few feet up the slope of dams is not necessarily a cause for apprehension if it is a permanent condition. Many existing safe dams are subject to such conditions.

New small springs are to be expected at the toes of some dams and in the abutments for quite a distance below the dam. These, of course, are not objectionable if of constant discharge and flowing clear.

In modern dam design, the probable elevation of the phreatic line and amount of seepage is estimated. If, during the course of filling the reservoir, it becomes apparent that the estimated values will be greatly exceeded, a thorough review of the design should be instigated.

Time of Filling Reservoir

It is always advisable to fill the reservoir for the first time very slowly. This will give all parts of the dam ample time to take final adjustments. If for no other reason, slow filling will reduce materially the expense of correcting minor and major defects if they should develop.

There is always the possibility of flood control dams filling very quickly at the first filling. Allowance should therefore be made in the design for such an eventuality, although, in most every case, the chances of the first flood, after the completion of the dam, being large enough to completely fill the reservoir is quite remote and a partial filling is almost always available for a partial test of the structure.

However, ample labor and material should be available if the first flood should be large enough to fill the reservoir completely.

Protection of Slopes

The slopes of the dam will, of course, have to be protected from wear. The downstream slope is subject to rain wash, spray from the reservoir and, in some cases, wind erosion.

The best protection for the downstream slope is, of course, a covering of coarse gravel or riprap, but this is usually too expensive. Grass is most frequently adopted for such protection.

The type of soil, the climate, the direction of the slope and other things vary exceedingly in different dams. It is therefore impossible

to make general recommendations. Sodding is seldom used, but sometimes a top layer of rich soil is placed before seeding.

It is difficult to get grasses to grow in sandy soil in some climates. Soil having an effective size of more than 0.2 mm. will usually absorb rain as fast as it falls. Where the climate is humid, grasses have been successfully grown on very sandy soil. Frequently a nurse crop is grown first to fix the soil after which a more permanent seed is sown. A number of experimental plots were sown with different grasses and combinations of grasses to determine the best type for the dams of the Miami Conservancy District (4).

Shrubs and small trees are not objectionable if the roots do not extend too close to the phreatic line and therefore do not tend to loosen the saturated part of the dam during heavy winds.

A coating of crude oil was applied (5) to the top and downstream face of the South Dike of the Sweetwater dam on the Sweetwater River, California, for such protection without much success. However, the Bureau of Reclamation is now making further investigation of its efficacy.

If the compaction of fine grained soils in rolled-filled dams has not been complete to the outer edges of each lift, there will be a layer of loose, unconsolidated material on the downstream face which will absorb the rain, become very unstable and subjected to shallow sloughing.

Such sloughing is unsightly but not necessarily disturbing, since the slope as a whole might be perfectly stable. Patience is required to get grass to grow on such slopes unless the loose surface is compacted, but it can be done.

Upstream slopes require protection from waves. So many types of paving for wave protection have been used that they cannot be described here. However, there are two very essential features common to all. First, the embankment surface must be well compacted. Second, between the paving and the well compacted embankment there must be a layer of broken stone or coarse gravel. The purpose is to act as a filter so that water draining out of the embankment and through the paving will not carry material and cause a void for the paving to fall into.

Paving is as strong as the proverbial chain with the weakest link. Allow one part to become damaged and give access for the waves to the underlying material, and large areas are undermined and damaged. It is therefore very necessary to keep such paving in constant and

complete repair.   Important dams with a long fetch to create high
waves are frequently provided with a stock pile of repair material
if such material is not available in the immediate vicinity.

Experience has indicated that rock riprap is superior to concrete
paving for wave protection.   In addition, waves will ride up the
face of riprap to only about half the height of that for concrete paving.

Burrowing Animals

There is a record (6) of one 56-foot western dam which is claimed
to have been destroyed by leaks started by burrowing animals.   In
other cases dams in the west have to be patrolled twice daily.   How-
ever, provision such as rock faces, concrete walls, etc. to make the
operations of such animals impossible are seldom resorted to.

In one case a distasteful oil was spread about (5).   The writer
has been advised that this oil has had its effect in keeping away
animals.   Usually the remedy is frequent inspection and a plentiful
supply of poison.   The writer knows of no trouble of this kind for
large dams in the east.

Soluble Material at Dams

In some cases dams have been built at sites where the earth founda-
tion or abutments contain soluble materials.

At an earth dam in California the abutments consist of shale with
seams of soluble gypsum.   Chemical analysis of the seepage water
indicated that 14 cu.ft. of solid volume of gypsum per day were going
into solution.   Grouting was resorted to which reduced the loss to
about 3 cu.ft. of gypsum per day.   This was in 1935.

As the reservoir contains water only about three months in the
year, this amounts to a yearly loss of about 270 cu.ft. or 10 cu.yd.
Although this seems a dangerous loss it was felt that some of the loss
may be coming from a considerable distance above the dam and
therefore, since 1935, the attitude has been one of watchful waiting.

Top of Dam

There is a tendency to neglect maintenance of the original level of
the tops of dams when they have lowered due to the wear of traffic,
wind, rain or spray wash, or settlement of the structure.   The tops
of many old dams are several feet below their original level.   Ob-
viously this reduces the available surcharge to pass flood water and
therefore is a dangerous condition.

The tops of some dams, composed of very clayey soil, are subject to deep cracking several inches in width at the surface. These cracks destroy the effectiveness of the dam and may be a serious source of weakness during high water. Several of such dams in Texas require continuous irrigation from a ditch on the crest to keep them saturated in order to avoid such cracks.

Spillway Control

It should be very apparent that the successful use of a spillway with or without controls depends upon the unaltered maintenance of the original design except with the advice of experienced dam engineers.

One of the most flagrant disregards of this principle was where a walkway, supported by steel members a few feet apart was installed on the crest. Drift from the first flood lodged on the supports and obstructed the spillway with disastrous results.

The writer had occasion to make recently a tour of inspection of a number of dams, the spillways of which were provided with the ordinary type of automatic flashboards. The original pins were carefully designed to bend over at a safe elevation of water surface. The writer found that the original pins, as called for on the plans, had in a number of cases been superseded by reinforcing bars, angle irons and even small rails, in fact anything that was handy. Some of these new pins were entirely too strong for safe conduct of floods. In another case automatic flashboard pins were strengthened by guy wires because, as the operator explained, they went out too often.

Earth dams equipped with manually operated spillway controls are at the mercy of the operating personnel. For this reason they should not be used for this type of dam unless the dam is of sufficient importance to necessitate the use of a force of mechanics on continuous duty and unless floods are exceedingly sluggish. Failure of power for operation, lack of maintenance of machinery, fixation by ice or drift and absence of operators at times of large floods may result in the overtopping and destruction of the dam.

In one instance the writer observed that a vertical pipe was installed adjacent to the supports of all gates, which apparently served no purpose. Upon inquiry he was told that this pipe would be loaded with dynamite and the supports blown up if anything happened to delay the necessary operation of the gates.

Something much better than this rather crude device is now being

adopted by the Aluminum Company of America for its Tainter gates. This consists of a tank built into the framework of the gate so located that overtopping of the gate a predetermined amount would fill the tank with water of sufficient weight to buckle the supports and destroy the gate.

Floods

The writer can recall that, prior to thirty years ago, a spillway designed to pass a flood 50 per cent larger than the largest flood which had occurred during a period of records as long as twenty-five years, was considered adequate. It is obvious that such methods were used by engineers at that time solely because other methods were not then available.

About 1914 the theory of probabilities was applied to flood studies; that is, curves were derived indicating by past records on a stream the frequency with which, during a long period, a given flood should be expected. Notwithstanding the fact that periods of records sometimes did not exceed twenty years and very seldom exceeded thirty or forty years, these probability curves were extrapolated to estimate the flood which would be expected, during long periods, once in 1,000, 5,000, 10,000 years, etc. Then according to the judgment of the engineer, the 1,000-, 5,000-, or 10,000-year flood was selected for the design capacity of the spillway.

So seriously was this method of estimating floods taken that numerous articles appeared in the technical publications defining more exact methods for such extrapolation by use of Pearson's and other functions, the writer included chapters on the methods in two books, other books included a description of the method, and the late Allen Hazen devoted an entire book to the subject.

Recently, however, it has been proven by advanced studies and a greater accumulation of data, that the probability method is entirely inadequate. Data on floods of many years ago and gagings of more recent floods have proven conclusively that there must be a combination of meteorological conditions which gives rise to storms of a special class which occur so infrequently that their resulting floods seldom appear on the published records of a given river. These storms and their resulting floods seem to be in a different class from ordinary floods and follow some law of their own.

Thus floods have occurred on rivers which, based upon probability studies of prior records of considerable length, would have a frequency

not of the usually adopted 1,000 to 10,000 years but a frequency of once in millions and even billions of years.

In 1932 the Devils River, Texas, experienced a flood 4.5 times that indicated as the 10,000-year probability based on previous records. The 1921 flood on the Arkansas River, Colorado, was five times the 10,000 year probability. These and several others like them are extreme cases. However, there are any number of cases where rivers have experienced floods much greater than the 10,000-year probability. For instance, the 1913 flood on the Hudson River at Mechanicville, N. Y., was over 1.5 times the 10,000-year probability.

However, there are hundreds of old dams in this country which have spillways designed to pass maximum floods determined by the probability method and the capacities of which have not been reviewed by the more advanced methods now being used. Many of them are entirely inadequate and it will be only a question of time before they will be overtopped. Some owners have re-estimated the flood probabilities for their dams and are arranging for increased capacities; but, for the most part, sufficient remedial measures have not been taken.

Testing Devices

Testing devices are usually installed in important modern earth dams to indicate, during and after construction, whether or not the dam is performing in the manner expected. A serious difference in performance from that assumed in the design of the structure should be cause for investigation. These devices consist of:

1. Piezometers to indicate the location of the phreatic line during and after filling the reservoir.
2. Pressure cells in hydraulic cores to indicate the load on the shells of hydraulic fill dams.
3. Weirs to measure seepage.
4. Monuments on the dam, the abutments, and adjacent foundations, referred to permanent monuments in the vicinity, to indicate vertical and horizontal movements.

Operating Routine

Frequent inspection of earth dams is a prerequisite to efficient operation. It is very difficult to set forth rules governing inspection since each case warrants different procedures. However, the following rules may be considered typical for cases where everything appears satisfactory.

A thorough examination of all accessible parts of the dam, the foundation and the abutments, including observations on all instruments and appliances provided for checking the performance of the dam, should be made once for each 10 per cent increase in reservoir level during the filling of the reservoir, but at least daily.

After the reservoir has been filled, such inspections should be made daily until the elevation of all piezometers and the quantity of seepage is constant and clear. Thereafter, such inspections should be made twice weekly for a month or two. Future inspections will be governed by conditions previously found. A thorough inspection spring and fall is quite advisable.

Sudden changes in performance as indicated by sudden changes in the trend of measurments and observations, evidence of piping, raveling of slopes, sloughing or any incident of an unusual nature should be reported without delay and inspections made more often.

Observations should be made of the upstream slope during each drawdown of the reservoir until experience has demonstrated the stability of the slopes for operating conditions.

Complete official records and reports should be kept of the results of all observations. The operator should be informed of the piezometer heights, seepage and movement of the dam to be expected and any material departure should be the subject of special and immediate reports.

It is evident that, if any serious trouble is encountered, indicating the probable ultimate destruction of the dam, the reservoir should be drawn down as quickly as possible.

References

1. HOLMES, W. H.   Earth Filled Dam Leakage Stopped by Grouting with Cement.   Eng. News-Rec., **98**: 900 (1927).
2. DeBERARD, W. W.   Conditions in Flood-Beleaguered Cairo.   Eng. News-Rec., **118**: 153 (1937).
3. High Earth Dam Threatened by Washout.   Eng. News-Rec., **100**: 750 (1928).
4. EIFFERT, C. H.   Tests in Growing Vegetation on Gravel Dams.   Eng. News-Rec., **97**: 55 (1926).
5. SAVAGE, H. N.   Sweetwater Dam Enlarged for Third Time.   Eng. News-Rec., **82**: 952 (1919).
6. CASE, C. B.   Hebron Earth Dam Washed Out.   Eng. Record, **69**: 629 (1914).

Discussion by *Frank A. Barbour*.*   Mr. Creager's paper is particularly valuable to operators, because of its emphasis of the fundamentals of maintenance.   Earth dams are important plant items in many water works systems.   General engineering interest in this type of structure has been stimulated in recent years by the rapidly increasing height and volume of such dams built and projected—largely in connection with the federal program of public works construction.

While in 1890, only five earth dams 100 feet in height had been built, today the total approximates 150, with one-tenth of this number in excess of 200 feet in height.   At the present time, a rolled fill earth dam 400 feet high is proposed to be placed in a narrow canyon on the White River, Washington, for the flood protection of Tacoma.   Both the hydraulic and the rolled fill methods of construction continue to be used, but the latter is gaining in attractiveness, due to increased size, power and speed, and resulting economy of available mechanical equipment—about two-thirds of the dams exceeding 100 ft. in height and built during the last ten years have been constructed by the rolled fill method.

The rapidly advancing science of soil mechanics has made possible a more rationalized design, on a strength versus stress basis, and thus has provided the confidence necessary for the undertaking of unprecedented heights, but it has not prevented some partial failures, and experience is indicating the necessity of caution in the application of laboratory tests.   Thus, it has been found that overcompaction is possible and that it should be limited to that degree which can be maintained after saturation by the weight of the overlying material.

The fundamental requirements are permanent stability against sloughing, when saturated and subject to the destabilizing effect of percolating water, and reasonable water-tightness.   The present standard design, therefore, includes a central impervious section to reduce seepage and pervious shells of necessary shearing strength to provide stability.   That no earth dam is watertight is more definitely recognized and emphasis is being placed on adequate drainage for the safe discharge of such seepage as passes the impervious section, or through the foundations.   Drainage is the present day watchword both in design and in the emergency correction of the effects of concentrated excess seepage.   In reference to internal drainage, it may be noted that the late Gardner Williams used transverse drains

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and surrounding filters carried well into the downstream third of the embankment before 1910.

Masonry core walls, even where the rock is close to the surface, are seldom used and even the value of a key wall to connect the earth fill with the rock is being questioned.

The soils laboratory has made possible the economic use of adjacent borrow pit material and the refinement of the embankment design. But such refinement is of little value, if the foundation, which frequently is the weakest element in the structure, is unstable—as has been indicated in the case of several major structures and recently found to be the explanation of the slip at Fort Peck dam on the Missouri River, Montana. The investigation of foundation materials requires the collection of undisturbed samples. Dependent on the number and validity of such samples will be the factor of safety to be applied to the laboratory results of shearing strength, amount and rate of settlement and permeability under loads. An earth dam holding 25 feet of water may seem to be a simple undertaking, but it involves real problems, if the foundation is sufficiently unstable.

Obviously, soils laboratory practice, the application of test results to design and construction, and the mechanical equipment now available, all form subjects for extended papers and all of these phases of the earth dam problem Mr. Creager might have competently elaborated. He has chosen as his major objective a demonstration of the fact that an earth dam is a plant unit requiring careful supervision and control and for sound diagnosis of internal condition, the provision of piezometers, settlement monuments, pressure cells and weirs for the measurement of seepage.

Perhaps, for the average superintendent, the most suggestive statement made by Mr. Creager is that many old spillways have inadequate capacity. About 40 per cent of the failures of earth dams are due to overtopping by flood flows and a few years ago, a member of this Association registered the opinion "that nearly all earth dams are doomed to washing out by large storms"—based on the fact that as the years go by, larger and larger peak run-offs are demonstrated to be possible.

Mr. Creager's presentation of the fundamentals of maintenance of earth dams will serve a very good purpose, if it induces operators to investigate and compare the spillway capacities of their dams with the flood peaks now recognized as possible and, perhaps, to take such action as may be necessary to discount overtopping.

The Valuation of Water Works Systems in Canada

By J. Clark Keith

A PUBLIC utility is an enterprise which renders a service or which supplies a commodity of general necessity or convenience to the public. There may be public ownership of the utility or the privilege of serving the public may be delegated to a private person. When the private person is a corporation, we have the public service corporation.

Value must be ascertained when the ownership of property is to be transferred from one person to another. When rates or prices to be charged for service are to be fixed, it is necessary to know the amount of capital which is *properly* invested. The real starting point in any valuation is the properly invested capital and the volume of the business which is transacted. A careful distinction must be drawn between the cost of an article and its value. The words are not synonymous and cannot be used interchangeably. The replacement cost today of a steam driven pump might be much in excess of its original cost when purchased 35 or 40 years ago and would bear no relation to its value when compared with an investment in some other type of pumping unit. Its present day cost might be much in excess of its true value as a pumping unit.

When property is to be valued for purchase or sale, both the seller and the purchaser desire to know the value as determined from the excess of the earnings over the cost of operation, including all fixed charges. An answer should be sought to the following questions: What did the property cost; what is the deferred maintenance or accrued depreciation; what is the cost of operation; what are the earnings, present and prospective; what are the profits, present and prospective.

The value of the going concern is the total value of the entire property, its market value. "Going Value" is the increment in value due to the fact that the business is established and in successful operation. A water works system with 10,000 services producing revenue would be in a very different position from one which had a distribution system capable of serving an equivalent number but without any services yet installed.

In making the valuation of the physical properties, account must be taken:

1. Of the cost of replacing each inventoried article with a new equivalent article.

2. Of the probable remaining term of usefulness of the item.

3. Of the probable term of usefulness of the same or an equivalent new article.

4. Of the cost of replacing the article with an equivalent article at the time when the article will probably be discarded.

An appraisal will begin with an inventory of the property which should be in sufficient detail to prepare an estimate of cost such as an engineer would make if called upon to construct a duplicate of the property to be valued. If figures of the cost of construction are available, they will aid materially in estimating the cost of reproduction. There may be a wide variation between the cost of construction, frequently referred to as the "historic cost," compared with the cost of reconstruction of the plant as it exists at the time of valuation. Generally speaking, valuations are based on the present value of the property "used and useful" devoted to the public use.

The reproduction cost of any item can be determined with reasonable accuracy. Depreciation is a lessening of worth which may result from any cause. Accrued depreciation is the difference expressed in money between the original cost of an article and its remaining value. The allowances for depreciation will affect the present value more than any other single factor. In practice it is usually computed from the replacement cost of the article, its probable life new, and its expectancy. The simplest method of determining depreciation and the one most frequently used is the so-called Straight Line Method, by which a constant percentage of the value is written off for each year of its life. Where an appraisal is being made when materials have an abnormal value such as prevailed about 1920, it would be more equitable to utilize an average price

value for a period of five years rather than that which actually prevailed at the time. This would apply both on enhanced and depressed costs.

The probable life of any particular element in a plant may be subject to rather wide differences of opinion. The investment in the distribution system will usually constitute the largest single item in the appraisal. While it is customary to assume the life of cast-iron mains in the large sizes as 100 years, authoritative opinion may vary from 50 years to the higher figure. On mechanical equipment such as pumps and motors, the probable useful life is greater today than that which was assigned to them 20 years ago. This unquestionably arises from the fact that they are of superior quality to similar equipment made two decades ago. As a consequence, depreciation percentages are likely to be lower today for many items than they were 20 years ago due to their greater service expectancy. All estimates of annual and accrued depreciation are based on premises which cannot be determined with accuracy. Consequently, estimates of depreciation are only approximations. There are no records available from which absolutely dependable tables of expectancy can be prepared such as are available from mortality statistics for human beings. The probable useful life or expectancy is merely the average life which is often not reached and just as often exceeded.

Arbitration is the generally adopted method of reaching a conclusion as to the value of a plant. The number of arbitrators and the method of their appointment is governed by statutory provision which differs in the various provinces. On the assumption that they have been named, they are presumed to be familiar with their legal limitations as well as their technical ability to deal with their assigned task. Many court cases bear testimony to their failure to be conversant with both of these requirements. They must first secure an itemized plant inventory from every available source—office records of the development of the utility from its inception if they are available; additional information from surveys both surface and underground carried out and under their own direction; memory records from long service or retired employees. No avenue of information can be overlooked. It may be safely said that no distribution system can provide a record of every special casting, bend, tee, offset, etc., which has been used throughout its development. Many small items in use, due to their underground location will be

overlooked. In this respect the valuation of an electric utility would be distinctly different where most of the structures are above ground.

With all information available, the method of procedure is rather definitely established throughout Canada. The general principle of reproduction cost new, less accrued depreciation, is provided for by statute and has been repeatedly upheld in the courts. Capitalized profits, franchise value, future earnings, goodwill, and other intangibles, if included, have a fair chance of being deleted on an appeal to the courts. The provincial statutes in some instances specifically exclude them as elements of value in rate making. As rates are a natural outcome of valuation, it would follow that they would be excluded in valuations as well.

The arbitrator for the vendor is expected to secure for his client a sum which represents a fair price for that which passes to the purchaser, who in turn through his representative should receive value for his outlay. The third arbitrator if appointed may agree or disagree with both on occasion. They cannot hope to have a common viewpoint on every question. In this respect they will not differ from the courts who may subsequently rule on their differences. There will be dissenting opinions there and it is not unknown for the courts to accept the minority award in valuation cases.

If there is mutual agreement on the unit costs of reproduction and in the rates of depreciation, the mathematical mechanics is a simple matter of computation. The following typical record sheets were taken from a valuation in Ontario in which two arbitrators agreed on the value of a water works at a price in excess of $700,000 after expropriation proceedings were instituted. There was complete agreement in their finding and as a natural outcome there was no appeal to the courts. The vendor was entirely satisfied at the time of sale; in the eight years during which the purchaser has had control of the property, it has been established that all charges—both capital and operating, could be met, and water rates could be reduced as a result of increasing cash reserves and current surpluses from revenues received. The computations shown as Schedules 1, 2, and 3, are merely excerpts from the valuation records dealing with mains, hydrants, and meters.

In the valuation there was agreement as to the following life for the respective materials: 4-inch water mains, 80 years; 6-inch water mains, and larger, 100 years; hydrants, 50 years; meters, 25 years; trucks and cars, 4 years; maps and records, flat sum allowed; brick buildings, 33 years; trenching machines, 20 years.

SCHEDULE 1
Present Value of Mains

YEAR	DIAM.	LENGTH	RATE	TOTAL VALUE	LIFE-TIME	YEARS IN USE	% TOTAL VALUE	PRESENT VALUE
	inches	feet			years			
Prior to 1899	3	1,285	$1.21	$1,554.85	60	36	40	$621.94
	4	10,273	1.42	14,587.66	80	36	55	8,023.21
	6	5,843	1.89	11,043.27	100	36	64	7,067.69
	8	4,205	2.61	10,975.05	100	36	64	7,024.03
	12	3,271	4.19	13,705.49	100	36	64	8,771.51
1900	6	636	1.89	1,202.04	100	30	70	841.42
	8	1,924	2.61	5,021.64	100	30	70	3,515.14
1901	4	1,870	1.42	2,655.40	80	29	63.75	1,692.82
	6	4,770	1.89	9,015.30	100	29	71	6,400.86
1902	4	1,166	1.42	1,655.72	80	28	65.0	1,076.21
	8	20	2.61	52.20	100	28	72	37.58

SCHEDULE 2
Present Value of Hydrants

YEAR INSTALLED	TYPE	NO.	RATE	TOTAL VALUE	LIFE	YEARS IN USE	% TOTAL VALUE	PRESENT VALUE
					years			
1890	2½" Only	7	$137	$959.00	50	40	20	
	2½" Box	2	167	334.00	50	40	20	$258.60
1896	2½" Only	7	137	959.00	50	34	32	
	2½" Box	4	167	668.00	50	34	32	
	2½" Well	2	217	434.00	50	34	32	659.52
1900	2½" Only	1	137	137.00	50	30	40	
	2½" Box	1	167	167.00	50	30	40	121.60
1902	2½" Only	3	137	411.00	50	28	44	180.84
1903	2½" Only	14	137	1,918.00	50	27	46	
	2½" Box	2	167	334.00	50	27	46	
	2½" Well	1	217	217.00	50	27	46	
	2½" x 4 Box	1	174	174.00	50	27	46	
	2½" x 4 Well	1	225	225.00	50	27	46	1,319.28

SCHEDULE 3
Present Value of Meter System

DIAM.	NO.	RATE	TOTAL VALUE	LIFE	YEARS IN USE	% VALUE	PRESENT VALUE
inches				years			
⅝	5,271	$14.20	$74,848.20	25	4	84	$62,872.49
¾	185	19.42	3,592.70	25	10½	58	2,083.76
1	116	28.80	3,340.80	25	11½	54	1,804.03
1½	53	50.00	2,650.00	25	12	52	1,378.00
2	57	81.10	4,622.70	25	14	44	2,033.99
3	38	155.00	5,890.00	25	13	48	2,827.20
4	14	275.00	3,850.00	25	13	48	1,848.00
6	6	500.00	3,000.00	25	11	56	1,680.00

Note: The average years in use of each size of meter was utilized in the computation.

When the value of the distribution system had been obtained on a unit cost basis, an allowance of 4 per cent on the present value was added for valves, valve chambers, Class C pipe, and sundry minor items. The "present value" of the distribution system was $432,042.97 compared with a reproduction cost of $504,880.25. This rather high value was the outcome of very extensive extensions in 1928 and 1929 just prior to the valuation. It was found that there were five different types of hydrants or methods of installation in the system. These required detailed consideration. An allowance of 3 per cent was added for carrying charges on inventory. When the total "present value" had been ascertained, 8 per cent was added for "Going Value," and the statutory 10 per cent as provided in the "Act." No item which was "useful and in use" was depreciated more than 80 per cent.

When some of the units of a water works system have been in use for a great many years, it frequently appears on inspection that they are in as good condition as when originally placed in service, and it might be difficult to substantiate the depreciation rates which are given common acceptance. A wrought iron intake which had been installed 50 years was found on examination to have its wall practically unimpaired. It can be frequently demonstrated through visual evidence that the facts as to the actual material condition are at variance with the value arrived at by arbitrary depreciation rates which have become accepted as standards. Unless some reasonable basis for determining depreciation had been adopted through custom and use, the valuation of a utility which is so largely underground would be very difficult and involved.

In dealing with the question of valuation from the national viewpoint—not as it prevails in any one province—it is necessary to refer briefly to the statutes which govern such procedure and to cite some cases which have reached the courts.

British Columbia Public Utilities Act

An Act to provide for the Regulation of Public Utilities, 1938, Chapter 47.

The Act does not specify the procedure to be followed in the valuation of properties for the specific purpose of a sale, purchase, or expropriation. There are restrictive, clauses however which would have a definite bearing thereon.

Clause 22: No public utility shall:

(a) Capitalize any franchise or right to be a corporation.

(b) Capitalize any franchise, right, permit, or concession in excess of the amount which, exclusive of any tax or annual charge, is actually paid to the Province or to a municipality or other public authority as the consideration for the franchise, license, permit, or concession.

(c) Capitalize any contract for consolidation, amalgamation, merger, or lease.

It is elsewhere provided in the Act that no public utility may sell its property or franchise or consolidate same with those of any other public utility unless the approval of the Commission is first obtained. The Commission may appraise the value of the property of any public utility and enquire into every fact which in its judgment has a bearing on the value, including the money actually and reasonably expended in that particular undertaking in order to provide proper service to the community served.

For the following opinion relative to the operation of the Act, the Association is indebted to Mr. A. L. Murray, Managing Director, General Utility Company Limited, Victoria:

"The Commission seem to think this power of appraisal was primarily for their guidance in considering the question of rates. Since however it appears in Part V of the Act which covers the general supervision of public utilities, I should think that they would be quite justified in invoking this power of appraisal if they wished, before sanctioning the sale or amalgamation of any public utility.

"The Utilities Commission is still too young (it was established in December, 1938) for any body of precedent to have become established from which one could probably deduce their probable approach to the subject of valuation of properties in the case of a sale."

Alberta Public Utilities Act

The Public Utilities Act, an Act to prescribe the Duties of the Board of Public Utility Commissions, Chapter 53.

Section 52: The Board (The Board of Public Utilities Commission) shall have power:

(b) From time to time to appraise and value the property of any public utility whenever in the judgment of the Board it shall be necessary so to do for the purpose of carrying out any of the provisions of the Act and, in making such valuation, the Board may have

access to and use any books, documents, or records in the possession of any department or board of the Province or any municipality thereof.

Section 68: No proprietor of a public utility shall:

Capitalize its right to exist as a corporation.

Capitalize any right, franchise or privilege in excess of the amount (exclusive of any tax or annual charge) actually paid to the province or any municipality thereof as the consideration therefore.

Capitalize any contract for consolidation, merger, or lease.

An appeal shall lie from any order of the Board to the Appellate Division, leave having been obtained from a Judge of the Supreme Court.

Saskatchewan Public Utilities Act

An Act respecting water, gas, and electric companies, Chapter 32.

The compensation to be paid for a system taken over by a municipality is to be determined by arbitration. The single arbitrator shall be a Judge of the Court of King's Bench named by the Attorney-General and an appeal shall lie from his award to the Court of Appeal whose decision shall be final.

Section 52: "In determining the compensation to be paid, the arbitrator shall consider the actual replacement value of the property taken over and purchased as a going concern, such actual replacement value not to include any value for franchise or value based on earnings or good will and shall make due allowance for depreciation, deterioration, wear and tear, obsolescence, and all other proper allowances."

Manitoba

The Municipal Act, Chapter 57, R. S. M. 1933.

Expropriation of land is provided for under Sections 386 and 387 for rural municipalities, villages, and towns. The procedure under expropriation proceedings is defined in the Manitoba Expropriation Act 23 George 5 Chapter 12.

The Municipal and Public Utility Board Act, 16 George V, Chapter 33.

Section 117: The Board shall have power:

(b) From time to time to appraise and value the property of any public utility whenever in the judgment of the Board it shall be necessary to do so.

Section 124: No owner of a public utility shall:

> Capitalize its right to exist as a corporation.

> Capitalize any right, franchise, or privilege in excess of the amount, exclusive of any tax or annual charge, actually paid to the Board, or any municipality thereof as the consideration therefor.

> Capitalize any contract for consolidation, merger, or lease.

In the four Western provinces the legislation is almost identical in its prohibitory clauses. Franchise rights or anticipated profits appear to be rather definitely excluded as elements of value. The Saskatchewan Act is somewhat similar to the provisions contained in the Ontario Statute in citing those factors which are to be recognized.

Ontario

Public Utilities Act, R. S. O., 1937, Chapter 286.

The valuation is to be determined by arbitration under The Municipal Act. Alternatively, the compensation may be determined by mutual agreement without arbitration. Where the electors of a municipality have by vote declared themselves in favor of acquiring a utility, the value of which is subsequently determined by arbitration, it is not necessary to submit again the question of its purchase to the electors. The Council may alternatively take proceedings to determine the value of the property in question without action by the electors, but in such case any money by-laws to pay therefor shall first require the assent of the electors.

The basis for valuation is defined under Section 60:

"The arbitrators in determining the amount to be paid for such works and property shall first determine the actual value thereof, having regard to what the same would cost if the works should be then constructed or the property then bought, making due allowance for deterioration, wear and tear, and all other proper allowances, and shall increase the amount so ascertained by ten per centum thereof, which increased sum the arbitrators shall award as the amount to be paid by the corporation to the Company with interest from the date of the award. (This clause remains unchanged from R. S. O. Ontario 1887, Chapter 164, Section 99—a matter of 50 years.)

"In Ontario there is no classical example of rate determination such as that of the Smyth vs. Ames case (169 U. S. 466) which established a precedent for many valuation cases. There it was the judgment of the court that, "in order to determine that value the

original cost of construction, the amount expended in permanent improvements, the amount and market value of its bonds and stocks, the present as compared with the original cost of construction, the probable earning capacity of the property under particular rates proscribed by Statutes, the sum required to meet operating expenses, are all matters for consideration and are to be given such weight as may be just and right in each case. We do not say that there may not be other matters to be regarded in estimating the value of the property. What the Company is entitled to ask is a fair return upon the value of that which it employs for the public convenience. On the other hand what the public is entitled to demand is, that no more be extracted from it than the services rendered by it are reasonably worth."

While the Ontario statute under which valuations are to be made is rather specific as to the principles to be observed and is in close accord with the Smyth vs. Ames decision, there is much room for divergent opinions when "all other proper allowances" are under consideration. In the four Western provinces, in Nova Scotia and New Brunswick, there is a Board of Commissioners established for the administration of their respective Acts. There is no Board so designated in Ontario.

Nova Scotia

The Public Utilities Act, Chapter 128.

Section 16: The Board may at any time with the assistance of such expert engineers, accountants, valuators, and others, as it deems wise to employ, enquire into the extent, condition, and value of the physical assets of any public utility or into the condition and value of the undertaking as a going concern.

Section 17: Where a valuation is ordered by the Board under the provisions of this Chapter, the Board may order that all costs and expenses of counsel, engineers, valuators, as well as the expenses of the members of the Commission while employed in and about the making of such valuation, shall be paid by the public utility whose assets and property are the subject of the inquiry and valuation.

All expenses in connection with a valuation ordered by the Board may be charged to the capital account of the utility concerned and added to the value shown by such valuation.

Section 18: The Board may at any time make a revaluation of such property.

Section 38: The Board shall ascertain and determine what are proper and adequate rates of depreciation of the several classes of property of each public utility.

Section 40: Every public utility shall furnish to the Board from time to time and as the Board may require, maps, profiles, contracts, reports of engineers, and other documents—to determine the value of the property of such public utility.

Section 41: Each public utility shall furnish to the Board whenever required in connection with any investigation by the Board, in such form and at such times as the Board shall require, such accounts, reports, and information as shall show in itemized detail—depreciation, salaries, wages, legal expenses, taxes, and rentals, quantity and value of material used, receipts from residuals by-products, services or other sales, total and net costs, net and gross profit, dividends and interest, surplus or reserve, prices paid by consumers and in addition such other items whether of a similar nature to those hereinbefore enumerated or otherwise as the Board may prescribe in order to show completely and in detail the entire operation of the public utility in furnishing its product or service to the public.

NOTE: Under the powers contained in the next preceding chapter the onus would rest on each public utility to provide the Board with an accurate valuation upon request.

New Brunswick

J. D. McKay, City Engineer, Fredericton, states that Provincial Expropriation Act is not applicable to Public Utilities.

The Public Utilities Act, Chapter 127.

The "Board" has power to regulate tolls and to require any public utility to answer specific questions submitted by it. There is nothing contained in the Act which deals with appraisals or valuations.

Prince Edward Island

There is no general procedure in any statute setting out the basis of utility valuations.

Quebec Public Service Commission

The Public Service Commission Act. R.S.Q. 1985.

Under this Act the Commissioners have extremely wide powers. They are cited as the responsible body for carrying out many duties

imposed under other statutes. Mr. Theo. J. Lafreniere, Chief Engineer, Department of Health, Quebec, states that the valuation of public utilities in urban communities comes under their direction. In rural areas it is carried out by arbitration, each side being represented, the third arbitrator being appointed by the Supreme Court. Conditions covering expropriation and valuation proceedings are usually set out at the time a franchise is granted. The Legislature has been and may be resorted to in fixing procedure.

The Expropriation Act, 1937, Chapter 93.

Section 3: The provisions of this Act shall apply:

    (a) To the exclusion of all others, in all cases of expropriation authorized by laws of the Legislature now in force (one exception cited);

    (b) In all cases of expropriation authorized by laws which this Legislature may adopt in the future unless they provide for a different mode of expropriation;

    (c) In all other cases of expropriation lawfully authorized and the mode whereof is not fixed.

Section 10: The Superior Court fixes the indemnity and the compensation. An appeal shall be to the Court of King's Bench from a judgment rendered under Section 10:

    (1) Upon the right to expropriate, in all cases.

    (2) Upon the award when it is at least Five Hundred Dollars.

In all other cases the judgment of the Superior Court is fixed.

Indemnity and Compensation—Section 14: The indemnity shall be fixed according to the value of the immovable or real right which is the object of expropriation and the damages occasioned to the expropriated party.

Section 15: The expropriated party shall be entitled from the mere fact of expropriation to additional compensation equal to 15 per cent of the indemnity contemplated under Section 14. Such compensation shall be added to the amount of the indemnity.

Section 27: Any application for expropriation submitted to the Quebec Public Service Commission or to any of its members and in which the trial was not begun at the 3rd of April, 1937, shall be proceeded with and adjudicated upon under the authority of this Act.

Court Decisions in British Columbia

*Corporation of the City of Cumberland, S.C.R., 1931, vs. Cumberland
Electric Light Company—An appeal from the Court of Appeal.*

An arbitration held under the authority of The Arbitration Act,
R.S.C., 1924, C. 13, to determine the price which the City of Cumber-
land was to pay for the undertaking, property rights, and privileges,
of the Cumberland Electric Light Co. Ltd.

The Cumberland Electric Light Company had a 50 year franchise
dating from 1901 subject to the rights of the municipality to purchase
the undertaking at any time at an agreed price or, in default of
agreement, by arbitration.   The arbitrators fixed the value of the
undertaking, property rights, and privileges at \$74,000, the sum of
\$36,000 being the value of the physical assets, made up of fixed
assets and supplies on hand.   The Court of Appeal held that the
agreement was giving the City the right to purchase the whole
undertaking, that the submission was to assess the value of the
"undertaking, property rights, and privileges of the Company" and
that the price to be paid should represent the value of the whole
undertaking and was not restricted to the "physicial assets of the
Company."   The Supreme Court after hearing counsel for the
appellant and respondent confirmed the decision of the lower court
and dismissed the appeal with costs.

In this case the profits of the unexpired term were included in the
valuation, made in conformity with the agreement between the
municipality and the Company, and not under any general statutory
provision.

*Supreme Court, Victoria, March 11, 1912.   Davie vs. City of
Victoria.*

"When a municipal corporation acting under the powers conferred
by Chapter 20, Statutes of 1873, takes possession of land in con-
nection with the construction of a water works system and the com-
pensation due the owner is fixed by arbitration, the Corporation
cannot abandon the proceedings and the owner is entitled to a
declaratory judgment to that effect."

A provision in a statute relating to the expropriation of lands that
the sum awarded is to be paid within six months after the award and
that "in default of such payment the proprietor may resume posses-
sion of the property" is not the land-owners only remedy but an

additional safeguard for him and the option it gives him is a weapon to compel reasonably prompt payment by the Corporation.

Judgment for plaintiff with costs.

Court Decisions in Ontario

Re Harriman and Town of Owen Sound, 1910.

An appeal from an arbitration award for land for water works purposes. The arbitrated value was set at $1,200, which was the amount tendered by the Corporation when notice of expropriation was served on the owners. The appellants original claim prior to court proceedings was for $4,000.

Justice Britton. "In every case where there is a decision by an arbitrator, judge or jury, upon evidence more or less conflicting, some evidence must be disregarded, if that effect is not given to it. An arbitrator is not obliged to accept as true and to give effect to the evidence of any particular witness. He may disregard it because he does not think the witness truthful or thinks the witness mistaken or not qualified to speak on the particular matter. As to the suitability of the property for a water works system that must have been considered more or less as it was because of suitability in a certain sense that the Corporation was taking it over.

There is no ground for the contention that in such a case as this there should be an arbitrary addition of 10 per cent because of compulsory taking. "This is a case where all the evidence of value seems to have been disregarded without leaving anything but the bare fixing of the amount by the Corporation. In the circumstances the award should not stand."

In the matter of an arbitration between the corporation of the Town of Cornwall and the Cornwall Waterworks Company.

In 1897 an arbitration took place between the Cornwall Waterworks Company and the Town of Cornwall under the 98th and following sections of R.S.O. 1887, Chapter 164, to determine the amount to be paid by the Town Corporation to the Waterworks Company for their works and property. From this award the Waterworks Company appealed. In delivering the appeal judgment, Mr. Justice Street said in part:

"I am of opinion that the arbitrators are required under the Act simply to value the existing property of the Waterworks Company, and not to make any allowance for compensation for future profits or for the taking away from it of the right to supply water to its

customers at a profit.   The charter of the company was accepted
subject to the right of the corporation to acquire it upon paying the
value of its works and property at the end of a specified time, and
any pretence of a right to compensation for profits is excluded by the
language of the Act declaring the basis upon which the sum to be
paid is to be arrived at.   The arbitrators are not necessarily to be
governed by the sum expended by the company in erecting the works
and purchasing the property, but they are to fix it at what the com-
pany at the time of the arbitration could have erected the works and
purchased the property for, making due allowance on the one hand
for wear and tear and on the other, perhaps for outlay incurred in
work of a necessary but experimental character.

"In such an arbitration the arbitrators are simply to value the
existing property of the Company at the sum it would cost to erect
the works and purchase the property, allowing for wear and tear and
perhaps for outlay of a necessary experimental character, but they
are not to make any allowance for future profits or for the taking
away from the Company the right to supply water at a profit.   In-
terest is allowable on outlay during the construction of the works but
not on the cost of construction after completion, and while the an-
nual revenue of the Company is less than the annual expenditure."

Appeal dismissed.

*In the matter of an arbitration between the corporation of the City
of Kingston and the Kingston Light, Heat, and Power Company.*

An appeal by the Kingston, Light, Heat, and Power Company from
an award of the arbitrators appointed in this matter or for an order
setting aside the award or referring it back to the arbitrators.

By agreement between the City of Kingston and the Kingston
Light, Heat, and Power Company, the former was to have the option
of purchasing and acquiring the works, plant appliances, and property
of the Company used for light, heat, and power purposes.   The
majority of the three arbitrators in fixing the value of the works,
plant appliances, and property, did not include anything for the
earning power or franchise and rights of the Company.   In the judg-
ment it was held that the arbitrators were right as it was provided in
the agreement.

"That in the event of the works, plant and property being acquired
by the corporation, the company shall cease to exist as a corporate
body for the purposes for which they are constituted, except so far
as may be necessary to wind up the affairs of the Company, and shall
surrender, assign, transfer and set over to the corporation all their

rights, franchises, privileges and immunities." That is, the corporation having acquired the tangible property at a price to be fixed by arbitration, the company ceases to exist and, as part of the bargain, surrenders or yields up without other consideration their franchise and rights."

Held "that there being here no expropriation but a voluntary agreement and submission, the provisions of R.S.O. 1887 as to adding ten per cent to the amount ascertained by the arbitrators as to value had no application.

"The ten per centum to be allowed by this section is when there has been an expropriation by the Corporation of the Company's property under the Act, and is allowed apparently as consideration for the exercise of that right of expropriation, and as compensation for disturbance and for the interference with the determination of the Company's rights and privileges against the assent of the Company.

"It is entirely different in this case. There has been no expropriation. The submission to arbitration is voluntary, the terms and conditions are expressed in the agreement; nothing is there said as to any allowance of ten per centum."

It appears from the various Ontario appeal decisions that the majority are definitely committed to the idea of making the "fair value" the "present value" of the property in question as a basis of all calculation as to the value to be placed upon it. There is a definite disposition on the part of the courts to make allowances for tangible values only unless otherwise definitely provided for in an executed agreement.

In an appeal before the House of Lords (1893) A C 444–449 by The Stockton and Middlesborough Water Board against a decision of the Court of Appeal in a valuation involving the Kirkleatham Local Board, the same general principle was confirmed and the appeal dismissed.

Held "that upon the construction of the Special Act the word 'price' meant price and not compensation, and that in fixing the price, the basis of calculation should be merely the value of the mains, pipes and fittings regarded as plant in situ capable of earning a profit and that the arbitrator must not include in the price, compensation to the Board for the loss of the right to supply water within the outlying districts."

The award was fixed at 8,006 pounds under the judgment rather that at 25,424 pounds when compensation was involved.

Court Decisions in Quebec

Fraser vs. City of Fraserville—Judicial Committee of the Privy Council, 1917.

The possibility of an added utility for an expropriated property due to existing possibilities of development is, subject to limits, a right and proper subject for consideration in awarding compensation on expropriation, with all its existing advantages and all its possibilities, excluding any advantage due to the carrying out of the scheme for which the property is compulsorily acquired.

Appeal from the Judgment of the Quebec Court of King's Bench.

Under Section 5795 R.S.Q. arbitrators were appointed in July, 1911 and made the award which was in question in these proceedings. In the Supreme Court, Billeau J. made this statement:

"They (the arbitrators) have in the case above stated, made the mistake of making the expropriation share the profits of the greater value given to the property by the realization of the object for which it was acquired.   They make the City pay not only the value of a water power developing 300 h.p. which is *what the owners sell* but half of the value of an additional 1,200 h.p. which is what the City must realize by the execution of the works it has in view.   This is not the value to the vendor but the value to the purchaser.   The vendor receives more than he gives, he shares in the value of the property to the purchaser.   This is the indemnity which the City is called to pay.   I repeat this principle is wrong and vitiates the proceeding of the arbitrators."   This statement was read into the appeal judgment.

"The value to be ascertained is the value to the seller of the property in its actual condition at the time of expropriation with all its existing advantages and with all its possibilities excluding any advantage due to the carrying out of the scheme for which the property is compulsorily acquired, the question of what is the scheme being a question of fact for the arbitration in each case."   It is this that the Courts have found the arbitrator has failed to do and it follows that this award cannot be supported.

Town of Montmagny vs. Letourneau—Supreme Court of Canada, 1917.

· *Arbitration—Conclusiveness of award:* Appeal from the judgment of the Court of King's Bench appeal side, reversing the judgment of Flynn, J. in the Superior Court of the District of Montmagny which

maintained the action of appellant and quashed the award as granting an excessive indemnity.

The appellant by expropriation proceedings had obtained a servitude over lands of the respondent for laying and maintaining a pipe line. In due course an arbitration took place to decide the amount of compensation payable to the respondent. In these proceedings the appellant is resenting payment of the amount awarded.

Article 5797 of the R.S.Q. provides that the award of the arbitrators shall be final and without appeal. The decision in this case was similar to that in Fraser vs. City of Fraserville, in which it was laid down by the Privy Council that the value to be ascertained was the value to the seller and not to the buyer. The award of the arbitrators could not be disputed under the statute unless it was established that the arbitrators had exceeded their jurisdiction.

The appeal was dismissed with costs.

What reasonable inferences and deductions may be drawn from Legislation and Court Decisions in Canada?

(1) That reproduction cost new less depreciation is the broad basis on which valuations are to be determined.

(2) That material values only and not intangibles are to be given consideration unless otherwise specifically provided for under some contract or agreement.

(3) That the legislatures in some provinces recognize the difficulty of distinguishing between material and intangible values and for this reason definitely cite those elements which are not to be included in the valuation.

(4) That the experience under the Ontario Statute has been sufficiently satisfactory for it to remain unchanged for more than 50 years.

(5) That the vendor is entitled to additional compensation where expropriation and arbitration are resorted to as evidenced by the 10 per cent and 15 per cent increase provided in the Ontario and Quebec statutes respectively.

(6) That the majority award is not always right as shown by court decisions.

(7) That the value to the vendor has priority to that of the purchaser.

(8) That Courts of Appeal and Privy Council judgments are in accord on the principle of utilizing reproduction costs less depreciation.

Water Works Valuation for Rate Making in U. S.

By John P. Wentworth

VALUATION practice in the United States has been a contro-versial issue for many years. Courts and commissions do not agree on the fundamental principles of valuation. The purpose of this paper is to discuss the various methods of valuation and the trends in practice in recent years.

Today, practically every state has a regulatory commission with rate-making powers applicable to public utilities. Such a commission is usually known as a Public Service Commission, Railroad Com-mission, or by some similar title. The commission generally has authority to fix reasonable rates for public-utility services. Such rates can usually be established only after an investigation and public hearing, held upon the initiative of the consumers, the utility or the commission itself. After the hearing, in the light of the evi-dence presented and of its own investigation, the commission reaches a conclusion as to the value of the property, establishes the reasonable rate of return which the utility is entitled to receive and determines the necessary gross revenue. The commission then issues a schedule of rates designed to furnish such a gross revenue.

Either the consumers or the utility may request a rehearing be-fore the regulatory commission, should they desire to challenge the commission's findings. Failing to receive satisfaction after a review of the points at issue, either party may then take the case to the state court on points of law. The case may also be brought before the federal court by the utility, on the ground that the rates as fixed by the regulatory commission are confiscatory and are therefore in violation of the Fourteenth Amendment to the Constitution of the United States. When the case has once reached the federal courts

on the utility's initiative, the public has the same right as the utility to appeal to the United States Supreme Court, but such an appeal can be only on issues raised by the utility.

In most states the regulatory commission has authority to set aside contracts that have been made regarding rates, and to change rates that have been prescribed in a utility's charter or franchise.

There are several federal regulatory commissions, such as the Interstate Commerce Commission. This commission has jurisdiction over interstate carriers.

Theories of Valuation

Among the courts and regulatory commissions there are two principal schools of thought in regard to valuation, one favoring the "fair present value" theory and the other the "prudent investment" theory.

"Fair present value" as a rate base has been established as the "law of the land" by numerous decisions of the United States Supreme Court, beginning in 1898. In accordance with the rulings of the court, a public utility is entitled to charge rates that will yield a reasonable return on the "fair value" of the property devoted to the use of the public, provided that such a return can be earned by rates which are reasonable in the light of the worth of the service. The value referred to is value at the time when the service is being rendered. It must be fixed after due consideration of all relevant facts in each case. In most cases the important elements in determining fair value are the actual cost, the estimated reproduction cost, the condition of the property with reference to accrued depreciation, the financial history of the utility in operation, and its prospects for the immediate future, as indicated by trends of prices and business.

The "prudent investment" theory, on the other hand, has never been sanctioned by federal courts, although several public service commissions have favored it as the basis for establishing rates. This theory calls for a rate determined by the use of costs prudently incurred, or, if complete records are not available, costs which probably were, or should have been incurred. In other words, valuation on the prudent-investment basis involves determination of the actual, proper, original cost. In contrast to the "fair value," the amount prudently invested is a relatively definite measure of value.

There is a third, relatively small, group which favors the depreciated reproduction cost as the value of a property.

Present Legal Status of Valuation

The state regulatory commissions are far from unanimous in their preference for, and practice in regard to, valuation methods.

During the latter part of 1937, The Wall Street Journal of New York sent telegrams to 47 state regulatory bodies, including that of the District of Columbia, asking their attitudes on the use of various methods of valuation.[1] Of the 31 commissions replying to the telegrams, 23 indicated their practice and 20 indicated their preference. Obviously, some of the commissions reported both. Of the 20 which indicated their preference, 13 favored prudent investment or historical cost, while 7 favored the principles laid down by the U. S. Supreme Court. Of the 23 which indicated their practice, 6 have been using the prudent-investment theory, 1 reproduction-cost new less depreciation, and 16 the law of the land. Although most of the state bodies which replied apparently have been performing their functions in the light of Supreme Court decisions, the replies indicated that many are following that system only because they feel there is no alternative until the court changes its opinions.

Recently a plea that the Supreme Court reconsider the fair-value basis for public-utility rates was filed by the Department of Justice in a friend-of-the-court brief. This action was taken in the pending case of Driscoll v. Edison Light & Power Co. The federal government holds that this case offers an opportunity for a re-examination of the fair-value rule which has, the brief argues, "proved unsound in principle and unworkable in practice." In its place the government suggests as a suitable rate base the amount prudently invested in the property of the utility.

The fair-value rule, upon which the U. S. Supreme Court seems to have relied in all its subsequent decisions, was formulated in the case of Smyth v. Ames in 1898.[2] Justice Harlan, in delivering the court's opinion, said:

"We hold. . .that the basis of all calculations as to the reasonableness of rates to be charged by a corporation maintaining a highway under legislative sanction must be the fair value of the property being used by it for the convenience of the public. And in order to ascertain that value, the original cost of construction, the amount expended in permanent improvements, the amount and market value of its bonds and stock, the present as compared with the original

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[1] H. T. Rohs, Wall St. Jour., Dec. 28, 1937.
[2] 169 U. S. 466.

cost of construction, the probable earning capacity of the property under particular rates prescribed by statute, and the sum required to meet operating expenses, are all matters for consideration, and are to be given such weight as may be just and right in each case. We do not say that there may not be other matters to be regarded in estimating the value of the property. What the company is entitled to ask is a fair return upon the value of that which it employs for the public convenience. On the other hand, what the public is entitled to demand is that no more be exacted from it for the use of a public highway than the services rendered by it are reasonably worth."

Thus the Supreme Court established the fair-value rule, without defining exactly what it meant by "fair value." Subsequent decisions have served to clarify to some extent the meaning of this term, although the remark made by the court in Smyth v. Ames is still true, namely: "How such [just] compensation may be ascertained, and what are the necessary elements in such an inquiry, will always be an embarrassing question."

The Supreme Court has continually cited the Smyth v. Ames case. In the Minnesota rate cases, decided in 1913, the court reaffirmed its opinions and said[3]:

"The ascertainment of that value is not controlled by artificial rules. It is not a matter of formulas, but there must be a reasonable judgment having its basis in a proper consideration of all relevant facts."

In the Southwestern Bell Telephone Company case, decided in 1923, the court established the rule that current prices must be given due consideration in fixing fair value.[4] This decision definitely introduced the idea of future price trends and gave importance to prophecy as an element in the determination of the rate base. In this connection the court made the following statement:

"It is impossible to ascertain what will amount to a fair return upon properties devoted to public service without giving consideration to the cost of labor, supplies, etc., at the time the investigation is made. An honest and intelligent forecast of probable future values, made upon a view of all the relevant circumstances, is essential. If the highly important element of present costs is wholly disregarded such a forecast becomes impossible. Estimates for to-morrow cannot ignore prices of today."

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[3] 230 U. S. 352.
[4] 262 U. S. 276.

The advocates of the depreciated reproduction-cost theory believed that in the Indianapolis Water Co. case (1926) the U. S. Supreme Court made the reproduction cost at "spot prices," less "observed" depreciation, the controlling standard.[5]   In this case the court stated:

"It is true that, if the tendency or trend of prices is not definitely upward or downward and it does not appear probable that there will be a substantial change of prices, then the present value of lands plus the present cost of constructing the plant, less depreciation, if any, is a fair measure of the value of the physical elements of the property."

The Supreme Court emphasized the depreciated reproduction cost in the O'Fallon case (1929) when the court said:[6]

" 'The elements of value recognized by the law of the land for rate-making purposes' have been pointed out many times by this Court [citing cases].   Among them is the present cost of construction or reproduction . . .   The report of the Commission . . . carefully refrains from stating that any consideration whatever was given to reproduction costs in estimating the value of the carrier's property . . .   The Commission disregarded the approved rule and has thereby failed to discharge the definite duty imposed by Congress."

In explanation it might be said that Congress had directed the commission (Interstate Commerce Commission) in determining values to give consideration to all the elements of value recognized by the law of the land for rate-making purposes.

Some years later (1938), however, the Supreme Court definitely stated that reproduction cost did not furnish an exclusive test of value.   In the case of the Railroad Commission of California v. Pacific Gas & Electric Co., where the commission had found that the estimates of reproduction cost were erroneous and without positive value, the court stated:[7]

"Nor did the ruling with respect to the weight of evidence as to reproduction cost leave the Commission without evidence of the value of respondent's property.   We have frequently held that historical cost is admissible evidence of value . . .   While the court has frequently declared that 'in order to determine present value, the cost of reproducing the property is a relevant fact which should have appropriate consideration,' we have been careful to point out that

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[5] 47 Sup. Ct. Rep. 144.

[6] P.U.R., 1929C, 161.

[7] P.U.R. 21, 1938, 480.

'the court has not decided that the cost of reproduction furnishes an exclusive test.' "

In spite of this last warning on the part of the Supreme Court, an examination of its rulings relative to public-utility valuation leaves an engineer with the feeling that reproduction-cost new, less depreciation, is given the greatest weight in determining fair present value in accordance with the law of the land.

Minority of Supreme Court Favors Prudent Investment

In the Southwestern Bell Telephone case, mentioned above, Justices Brandeis and Holmes, although concurring in the result of the court's decision, issued a dissenting opinion, in which they challenged the fair-value rule and suggested the adoption by the court of prudent investment as the measure of the rate-base. Justice Brandeis, in delivering the minority opinion, said:

"I concur in the judgment of reversal. But I do so on the ground that the order of the State Commission prevents the utility from earning a fair return on the amount prudently invested in it. Thus, I differ fundamentally from my brethren concerning the rule to be applied in determining whether a prescribed rate is confiscatory. . . .

"The adoption of the amount prudently invested as the rate base and the amount of the capital charge as the measure of the rate of return would give definiteness to these two factors involved in rate controversies, which are now shifting and treacherous, and which render the proceedings peculiarly burdensome and largely futile. . . . It [the rate base] would, when once made in respect to any utility, be fixed, for all time, subject only to increases to represent additions to plant, after allowance for the depreciation included in the annual operating charges. The wild uncertainties of the present method of fixing the rate base under the so-called rule of Smyth v. Ames would be avoided."

In several later cases there have been dissenting opinions in which one or more judges favored the prudent-investment theory.

Last year, in the Indianapolis Water Co. case Justice Black, a new member of the court, in a dissenting opinion, criticized the reproduction-cost theory in the following words[8]:

"The determination by the court of appeals that the rates in the present case are confiscatory can only be supported, if at all, by giving undeserved weight to evidence given to support the 'reproduction

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[8] P.U.R. 21, 1938, 465.

cost' theory.   The experience of the people of Indianapolis in their efforts to obtain fair and reasonable water rates from this company . . . discloses what appears to me to be the complete unreliability of the 'reproduction cost' theory.   Wherever the question of utility valuation arises today, it is exceedingly difficult to discern the truth through the maze of formulas and the jungle of metaphysical concepts sometimes conceived, and often fostered, by the ingenuity of those who seek inflated valuations to support excessive rates . . . Completely lost in the confusion of language . . .   Commissions and courts passing upon rates for public utilities are driven to listen to conjectures, speculations, estimates, and guesses, all under the name of 'reproduction costs ' . . .   Courts have gone further and further away from considering cost in determining the value of utility property."

Going Value

The U. S. Supreme Court has often recognized "going value" as an element to be considered in valuation, without establishing definite rules to be applied in determining it.   In some cases, the court has allowed a separate item in the valuation for going value, while, in other cases, no additional compensation has been allowed, because the valuation of physical properties was predicated upon the assumption that the utility was a going concern.   In the Des Moines Gas Co. case in 1915[9], the court, dealing with the Master's report and the exclusion of a special item for going value, observed that the Master had "already valued the property, in the estimate of what he called its physical value, upon the basis of a plant in actual and successful operation."   As the Master had included overheads at 15 per cent in that valuation, in addition to organization expenses, the court was unable to hold that the element of going value had not been given due consideration.

There has been much criticism of the methods used by engineers in estimating going value.   In the Los Angeles Gas & Electric Corporation case in 1933, for example, two experts estimated going value by several different methods.[10]   In regard to these estimates the court said, "It is unnecessary to analyze the testimony of these witnesses, as it is obviously too conjectural to justify us in treating the failure to include their estimates as a sufficient basis for a finding of confiscation."

[9] 238 U. S. 153.
[10] P.U.R., 1933C, 229.

In a recent case the court in referring to an expert's testimony said, "His calculations depended upon assumptions of theoretical future deficits. They involved elaborate guess work, according to the assumed valuations of physical plant, the length of time required for the complete recovery of the business, and the rate of return." The court treated such speculations as "in no real sense evidence."

The controversy as to the proper method of estimating depreciation continues. The utilities, in making their returns for federal income-tax purposes, usually use the straight-line method. The Bureau of Internal Revenue approves of this method and has compiled tables to show the useful life of various kinds of structures. When the utilities have rate cases in court, however, they generally claim a lower depreciation, based on the sinking-fund method or on observed depreciation. Commissions are increasingly requiring the utilities to be consistent in their methods of figuring annual and accrued depreciation.

The higher courts have not established any particular method of estimating depreciation. They have, however, ruled that depreciation should be based upon the fair value of the property and not on cost.

Summary

There is a decided difference of opinion as to whether "fair present value" or "prudent investment" should be the basis of public-utility valuation. Several state commissions use "prudent investment," while others prefer it but do not use it, because they feel that it is contrary to the decisions of the United States Supreme Court. Ever since 1923, it has been apparent that a minority of the Supreme Court believes that "prudent investment" should be the basis of valuation. There is, at the present time, a valuation case pending before the Supreme Court, in which the Attorney General of the United States has argued that a re-examination of the fair-value rule should be made and that "prudent investment" should be adopted as the rate base.

It is quite evident that the question of valuation is still a perplexing problem. It is most difficult for an engineer to advise a client as to the value of a utility, because, regardless of the engineer's opinion as to the correct method of valuation, there is such a difference of opinion among courts and commissions. The determination of the value of a property is an embarrassing question, as a member of the highest court has said.

Some Features in Water Coagulation

By H. P. Stockwell

THE purification of water supplies by rapid sand filtration involves a chemical pre-treatment by which clay and other suspended impurities, organic color substances and bacteria are agglomerated into a flocculent precipitate to facilitate removal. The so-called floc particles are of such size and density that the greater part may be removed by settling in suitable basins, the small amount of floc which passes the settling basins being entrapped by the sand of the filter bed which serves to give the final polish to the water.

A large proportion of the impurities to be removed are in the colloidal state which means that the degree of subdivision is so high that the ratio of total surface to volume is very great and that phenomena associated with interfaces are of great importance, particularly adsorption and electrical charge. In most cases the colloidal particles bear a negative charge due to adsorption of negative ions, and the mutual repulsion of the similarly charged units tends to stabilize the colloidal system. In order to precipitate the impurities it is necessary to reduce these negative charges to some critical value by the addition of a coagulant which will contribute positive electrical charges in the form of ions and positively charged colloidal particles. Within certain limits of hydrogen ion concentration or pH, adsorption of the positive ion and mutual coagulation of the oppositely charged colloidal suspensions then takes place, which carries down the undesirable impurities in small discrete flocculent or gelatinous masses which mechanically sweep any larger particles of suspended matter from the water.

The most efficient coagulants are salts of those trivalent metals which yield hydrous oxides on hydrolysis; these ionize to give cations

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or positive ions of much greater coagulating power than do salts
which give cations of lesser valence.   The coagulant in widest use
is aluminum sulfate, commonly called filter alum though not a
true alum in the chemical sense.   On solution in water a precipitate
of hydrous aluminum oxide is formed, with which are associated the
adsorbed impurities.   The pH zone in which flocculation takes place
is dependent upon the anions and colloidal impurities present in the
water.   As a rule soft colored waters are coagulated with alum at
some pH between 5.0 and 6.2 while hard, uncolored and moderately
turbid supplies are coagulated at a pH slightly above neutrality,
that is, above 7.0.   This optimum pH for precipitation is not a
characteristic of the coagulant or of the water alone but of the two
taken as a combination and will vary for different water supplies.
Seasonal changes in the raw water will also require corresponding
changes in the optimum conditions for coagulation.   The presence
of the sulfate ion in alum is beneficial as it widens the pH range over
which alumina is precipitated.

Other commonly used coagulants are certain salts of iron, including
ferric sulfate, ferric chloride and chlorinated copperas.   Ferrous
sulfate (copperas) ionizes to give the divalent ferrous ion which
has only a small fraction of the coagulating power of the trivalent
ferric ion, consequently it is usually oxidized by the addition of
chlorine or lime.   In alkaline solutions, about pH 9.0, the ferrous
iron in copperas is rapidly oxidized by dissolved oxygen in the water.
When copperas and lime are used a softening reaction also occurs
which makes the method of special benefit in the treatment of water
of higher alkalinity.   Also, because of the high pH, manganese is
removed by this treatment.   The iron salts give a heavier and faster
settling floc than alum and this floc is insoluble at higher pH values
than is the alum floc.

Sodium aluminate is another coagulant often used either alone
or in conjunction with alum or copperas.   It gives a more rapidly
forming and larger floc than alum without formation of sulfate or
permanent hardness.   It cannot be used alone to treat waters bearing
much turbidity or color as it does not yield the positive trivalent
aluminum ions required for efficient coagulation of negatively charged
colloidal impurities.   The use of Bentonite, a colloidal clay, has
been recently proposed, the chief advantage being that it provides a
greater volume of faster settling floc than alum.   It is precipitated
by alkalinity in the water and would not therefore be so suitable for

very soft waters. Titanium salts have been investigated and the results are said to be very favorable. It is very probable that other substances will be found to have the necessary coagulating and adsorptive properties for use in water clarification. Chemical analysis of the water supply is not sufficient to indicate the most suitable coagulant, this being best determined by laboratory experiment augmented if possible by trial on experimental plant scale.

In addition to the true coagulants, there are certain finely divided substances which are sometimes used to improve floc formation. These may serve to weight the floc and thus improve settling or may function as binders to promote larger agglomerates than would otherwise be formed. In this group can be included activated carbon, also finely divided "loading material" such as clay or other added turbidity. Special reference should be made to the important research of Baylis at Chicago, on the use of acid-treated sodium silicate solutions as an aid to coagulation (Jour. A. W. W. A., **29:** 1355 (1937)).

Inasmuch as floc particles develop by a process of aggregation of smaller particles, stirring or conditioning is necessary to bring the smaller particles into collision with each other. Again, while the finest of turbidity is very definitely of colloidal dimensions, there are coarser suspended particles present which are removed by entrapment in the floc particle as it builds up. A slow stirring motion provides the necessary opportunity for both of these processes to take place. A preliminary rapid mixing is usually employed which may be accomplished by passage through a centrifugal pump, the coagulant being added at the suction well of the pump lifting the water to the mixing tanks. This is followed by slower stirring or conditioning at a rate of from 1 to $1\frac{1}{2}$ ft. per second for a period of sufficient duration to allow good floc formation, usually about forty minutes.

This conditioning may be carried out by passage through baffled mixing tanks, these being favored in smaller plants; by mechanical agitators or flocculators, which because of higher initial cost are generally found only in larger plants; or by causing the water in passing alternately upwards and downwards through a series of tanks to describe a spiral type of flow. This spiral flow is promoted by tangential application and removal of the water under just sufficient head to give the required mixing velocity. With tanks of rectangular cross-section smaller eddy currents are set up by the

pulsating effect at the corners which assure efficient conditioning of the floc.

Certain impurities, notably organic color, act somewhat as peptizing or deflocculating agents and tend to promote colloidal dispersion of floc; in some such cases mechanical types of mixing devices will not give satisfactory results, the floc being too delicate to withstand the slight beating action of the stirring arms. For this reason the spiral flow type of conditioning is the most satisfactory for the coagulation of water bearing organic coloring matter, although the method has also a much wider field of application, the elimination of the cost of installation and operation of mechanical stirring apparatus being a decided advantage. It is essential that all openings and ports through which coagulated water passes be of such sufficient size that the velocity is not increased to the point where floc is disintegrated; colored waters being particularly susceptible to this owing to the fragility of the alumina-color floc.

Many surface waters bear this colored organic content which differentiates the type from other natural supplies. They are found in widely scattered parts of the United States, notably in northern Wisconsin and in the Southeastern States. In Canada their occurrence is widely distributed, being found particularly in northern Ontario and Quebec and parts of the Maritime provinces, in fact, wherever there are deposits of disintegrating woody and vegetable materials, organic color substances will be leached out by the drainage from the area. Because of the prevalence of these colored waters in those parts of Canada associated with the rapidly developing mining industry and with the pulp and paper industry, they assume special interest and merit consideration as a distinctive type of water treatment problem. The coagulation of these colored water supplies differs especially as regards optimum conditions for floc formation and the character and fragility of this floc. The colloid chemistry involved would also appear to be somewhat more complex than in the treatment of uncolored water supplies although the same coagulants are employed.

The colored impurities consist of a mixture of organic compounds representing various stages of decomposition of the many components of wood, bark, and other vegetable growth. The terms humic acid and humates are generally used in referring to this mixture of color substances, the greater proportion of which are of colloidal dimensions. This may be demonstrated by the very slow rate of diffusion

through parchment paper and they may be separated from simpler molecular compounds by dialysis using such a membrane. Electrophoresis experiments show that the particles migrate to the anode under the influence of an applied electromotive force and they therefore bear a negative electrical charge. The molecular structure of these compounds has not yet been worked out but much research is being carried out especially in the fields of fuel and soil chemistry. The humic substances in peat, lignite, coal and similar deposits of vegetable origin as well as in soils, particularly forest soils, are the subject of extensive investigation.

Research May Lead to Commercial Use of Sludge

It is probable that so-called humic acid is chiefly a breakdown product of lignin which forms 25 to 30 per cent of wood by weight and on which much research is being carried out by the various research organizations dealing with forest products. Enormous quantities of lignin reaction products are discarded as waste in the chemical pulping processes and methods of commercial utilization are constantly being sought. One modern process successfully converts lignin in waste sulfite liquors into vanillin which is sold for the preparation of artificial vanilla. The progress of these somewhat parallel lines of research will be of influence in clarifying the chemical story of colored water and may eventually point to some possible commercial use for settled floc or sludge, the waste product of the purification process.

Humic acids are known to contain phenolic (—OH) and carboxylic or organic acid (—COOH) groupings and are therefore capable of yielding corresponding salts called humates. They are easily peptized or colloidally dispersed by alkali giving a dark amber colored solution. On acidification of the alkaline solution humic acid is partially precipitated or "salted out" leaving a solution of pale straw color; some workers denote the acid soluble portion as alpha-humic acid and the insoluble portion as beta-humic acid.

At the dilute concentrations found in natural water supplies an increase in color intensity is observed with change from acid to alkaline pH values. In fig. 1 are shown curves denoting this color change for two natural supplies and a filtered tap water. Such a color change indicates some physical or chemical change in the organic constituents and may be due to a change in the degree of ionization or to change from free humic acid to the corresponding humates.

This color change cannot be overlooked where filtration is followed by an alkaline protective treatment against corrosion. In this case the color of filter effluent must be such that the increased color after alkali addition will not exceed the desired standard. Where color is coagulated as a color-lake the optimum pH conditions are such that most if not all of the color substances are in the light colored and lesser soluble acidic state and this may be of some significance.
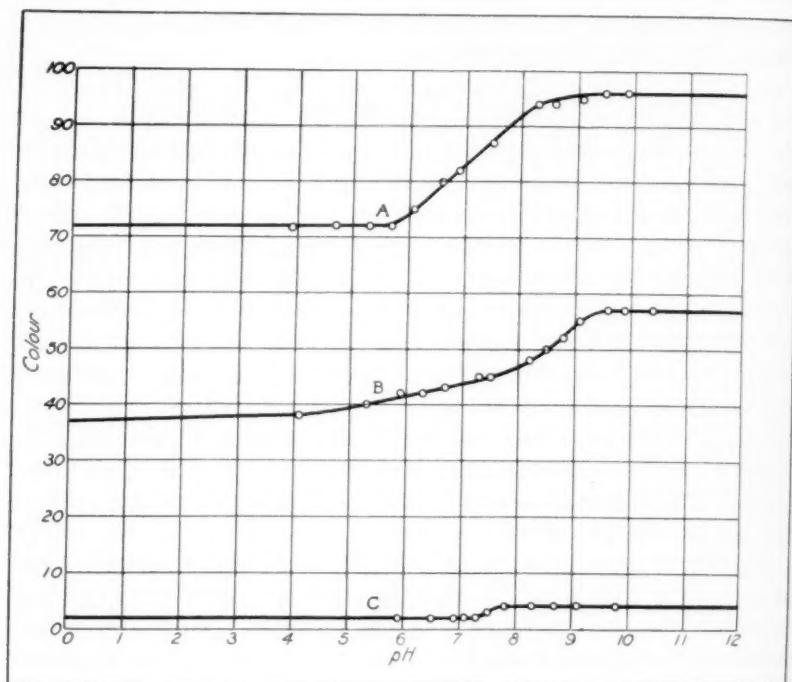
Fig. 1. Curves showing relationship between pH and color in: (A) Kentville, N. S., raw supply; (B) Ottawa, Ont., raw water; (C) Ottawa, Ont., filtered supply.

Somewhat parallel cases are to be found elsewhere in applied colloid chemistry. The organic dyestuffs which form lakes with alumina or other mordant belong to the class of acid dyes; again, in the sizing of paper, rosin which is chiefly abietic acid is added to the pulp as a colloidal aqueous solution prepared by partial saponification of the organic acid. It has been found that best size retention is obtained if the mixture of pulp and water containing the rosin

size is adjusted with alum to an acid pH similar to that which gives best color removal in water purification, under which conditions the rosin is carried down as an alumina-rosin adsorption complex. This last process could probably be best viewed as the coagulation of rosin as a colloidal impurity in the water, the best conditions being determined by the characteristics of the water which suspends the rosin and pulp, the pulp fibers, being negatively charged, filling a rôle similar to that of the Baylis silica sols, the small floc particles being attracted to them and thus retained in the sheet when the paper is formed.

Sludge from the settling basin in filtration plants affords a huge source of concentrated humic color material for study. If iron is allowed to rust in colored water a gelatinous corrosion product is formed which contains much humic color; this may be extracted with a weak solution of ammonia or alkali. It is interesting to note in this connection that a process has been developed in Europe in which water after being thoroughly aerated is passed through iron filings to effect color removal. Solution of iron occurs, floc is formed and the water is then filtered through a bed of roasted dolomite in granular form.

We have already noted that good flocculation and color removal with this type of water require a definitely acid pH condition, the pH range being usually between 5.0 and 6.2 if alum is the coagulant used and about pH 4.5 if iron salts are employed. Natural water supplies which are slightly acid or contain little alkalinity to buffer the reaction require less coagulant than those of alkaline pH or of higher alkalinity. Thus the cost of treatment reflects the soil characteristics and geological environment on the water shed. Seasonal variations in dosage requirement will be introduced by several factors, including changes in water temperature and changes in relative run-off from the different sections of the area; this last being dependent to some extent on the geography of the region as precipitation and the times of freeze-up and thaw in widely separated parts of the drainage area may vary.

Water dissolves carbon dioxide derived both from the atmosphere and from decomposing organic matter. Pure water in contact with air will dissolve up to 0.03 per cent by volume of carbon dioxide and will reach a pH of 5.7. In solution some of the dissolved gas combines with water to form carbonic acid which, being a very weak acid, is only very slightly ionized. The presence of this carbonic acid

makes possible the solution of calcium and magnesium as bicarbonates. While atmospheric carbon dioxide is always available, the supply of alkaline constituents depends upon the characteristics of the drainage area. The ratio and concentrations of this acidity and alkalinity are a determining factor in regard to the amount of alum required for coagulation. If little alkalinity is dissolved, carbonic acid remains free, the pH is low, and the color will be removed with a minimum of coagulant. On the other hand, if there is much limestone or dolomite on the watershed, alkalinity will be dissolved, ionization of free carbonic acid will be reduced and the water will require larger dosages of the coagulating chemical.

TABLE 1

Characteristics and alum requirements of water from some rivers tributary to the Ottawa river

RIVER	MILEAGE UPSTREAM	pH	COLOR	ALKALINITY	COAGULATION WITH ALUM		
					Dosage g.p.g.	pH	Color
Ottawa...............	0	7.1	45	21	$2\frac{1}{4}$	6.0	4
Mississippi...........	41	7.5	45	74	$3\frac{1}{4}$	6.7	11
Madawaska...........	45	7.3	45	40	$2\frac{7}{8}$	6.5	7
Bonnechere...........	56	7.4	35	59	$3\frac{1}{4}$	6.7	8
Petawawa............	122	6.7	45	11	$1\frac{1}{2}$	5.3	6
Dumoine.............	167	6.5	45	14	$1\frac{3}{4}$	5.7	7
Mattawa.............	212	6.7	35	13	$1\frac{5}{8}$	5.6	6
Ottawa...............	215	6.7	50	19	$2\frac{1}{4}$	5.7	6

In table 1 are given data relating to certain tributaries flowing into the Ottawa river above the city of Ottawa, Ontario. The Mississippi, Madawaska and Bonnechere rivers drain from an area with extensive limestone deposits and the water in each of these is of comparatively high alkalinity and requires relatively high alum dosages for coagulation. The others are from geological areas of igneous and metamorphic rock and are of low alkalinity, and smaller alum dosages suffice. The alum dosages given in the table are those required to give a fairly well formed floc; better color removal would be obtained by using a slightly higher dosage. An interesting seasonal effect is noted at Ottawa in the spring; the first flood waters being from the limestone area while later the flood waters from more remote parts of the watershed reach the city, these last being of very

low alkalinity.   Alum dosages change from the yearly maximum to the minimum within two or three weeks.

When alum is added to a colored water, ionization takes place, releasing the positive trivalent aluminum ions so effective for coagulation, this taking place under acid pH conditions. Hydrous aluminum oxide is then formed with which are associated the color, turbidity, bacteria, and sulfate and other adsorbed ions, forming the alumina-color lake or floc.   Ionization of the alum also yields sulfate ions which react with the natural bicarbonates in the water to form calcium and magnesium sulfates and liberate carbonic acid which gives the correct acid pH condition for floc formation.   Thus the addition of alum may be considered as equivalent to the addition, in proper form, of two reagents, colloidal hydrated alumina and sulfuric acid.   The requirements of the water treatment in respect to these two components may not necessarily be in the ratio in which they are combined in alum.   The required dosage of the sulfuric acid component is that which will produce the optimum pH for color removal and is more specific than the dosage of alumina required which may be present in moderate excess without interfering with the result.   Usually for a colored water of pH near the neutral point the acid requirement will determine the alum dosage and alumina will be in excess.   In this case savings can be effected without detriment to color removal by substituting sulfuric acid for part of the alum, the most significant result of which will be a narrowing of the pH range for good color removal.   In the treatment of some water supplies especially those of quite acid pH, flocculation is aided by the addition of alkalinity.   In such instances, in order to have enough alumina to carry down the impurities, the necessary alum provides acid in excess and partial neutralization is required to arrive at the optimum pH condition.

Adjustment of raw water pH with sulfuric acid involves reduction of pH and alkalinity with increase in the carbon dioxide and acidity. The sulfuric acid reacts with the bicarbonates in the raw water according to the equation:

(a) $$H_2SO_4 + Ca(HCO_3)_2 = CaSO_4 + 2\,H_2CO_3$$

Addition of alum then increases the calcium sulfate and carbonic acid as follows:

(b) $$Al_2(SO_4)_3 + 3\,Ca(HCO_3)_2 + 6\,H_2O =$$
$$3\,CaSO_4 + 2\,Al(OH)_3 + 6H_2CO_3$$
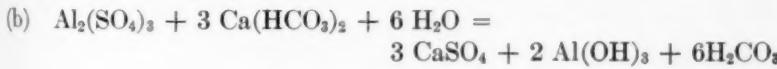
At definitely acid pH values some of the sulfate radical remains associated with the aluminum, therefore the amount of carbonic acid will be slightly less than represented by the equation. The total carbonic acid resulting from reactions (a) and (b), together with any free organic acid gives the necessary hydrogen ion concentration. This method of pH adjustment is quite practical and has been employed in plant operation but it is generally ruled out because of mistrust on the part of the consumer. Public opinion is not always favorable to the use of mineral acid in the purification of the public water supply.

If the natural water supply is already of acid pH a smaller dosage of alum is required than when it is neutral or alkaline. This is shown by the following comparison between two samples of similar alkalinity and both of low turbidity but from different sources and of quite different pH:

SOURCE	pH	ALKALIN-ITY	COLOR	REQUIRED ALUM DOSAGE
Kentville, N. S.	6.3	12	140	$1\frac{1}{2}$ g.p.g.
Ottawa, Ont.	7.0	12	45	2 g.p.g.

The first sample has about three times the color of the Ottawa water, sampled at the time of late spring floods, but the alum required for removal is 25 per cent less due to the lower pH. This would indicate that the amount of color appears to have less influence on alum dosage than the acidity.

While it is recognized that acidity in these colored waters, although expressed in terms of carbon dioxide, may be due in part to the organic acids present, these observations would suggest that carbon dioxide might be used for pH adjustment. By this method acidity is increased without change in alkalinity. Coagulation experiments have shown that good flocculation and color removal with reduced alum dosages are easily obtained and this would indicate that a possibility exists of effecting real savings in coagulation cost by a means which should be acceptable to the general consumer. It should not be difficult to add moderate amounts of carbon dioxide to a water such as that at Ottawa, with a yearly average pH of 7.0 and alkalinity of 20. Reduction in permanent hardness due to the alum would result, with a slight increase in the bicarbonate hardness after the filtered water is treated with lime for protection against

corrosion.   Methods of production and application of this gas are
well developed, recarbonation being one of the more important unit
treatments in water softening.

In fig. 2 are shown the relationships between acidity, alkalinity
and minimum dosage of alum for floc formation.   The experiments
were carried out using Ottawa river water of color 50 to 55; alkalinity
22 p.p.m.; pH 7.1 and acidity 1.0 p.p.m.   The necessary adjustments
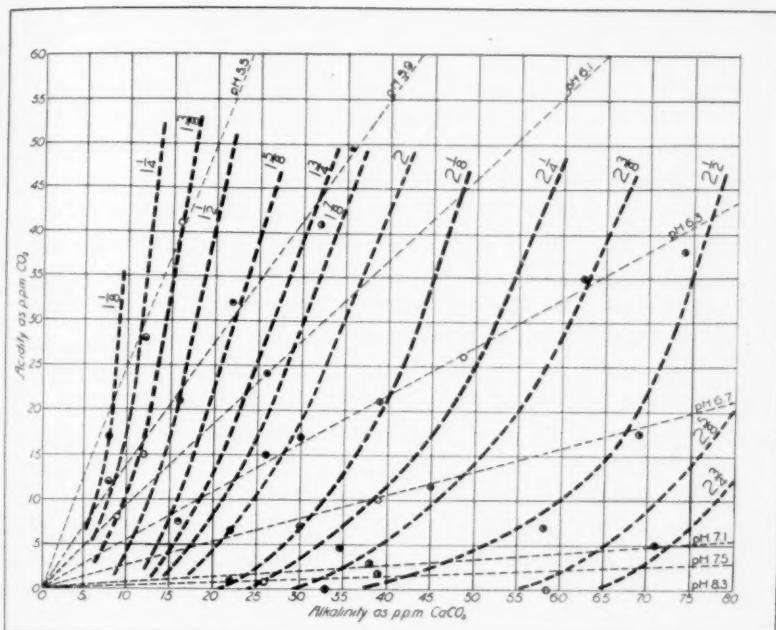
FIG. 2. Curves showing minimum alum dosage for floc formation in grains
per Imperial gallon for Ottawa raw water adjusted to various values of alka-
linity and acidity.

were made using carbon dioxide to increase acidity; sulfuric acid to
reduce alkalinity; in some cases aeration to reduce acidity; and a
solution of calcium bicarbonate made by passing carbon dioxide
through a suspension of chalk in river water and then filtering, used
to increase alkalinity.   The samples of water adjusted in these va-
rious ways were subjected to coagulation tests on a Baylis mixer at
30 r.p.m. for 30 minutes.   The dosage which gave only a noticeable
pin-head floc was then noted and plotted on the chart which therefore

shows the minimum amounts of alum which will give flocculation in this time.

Referring to the chart the following points will be noted:

1. Alum dosage increases with increased alkalinity of the raw water.

2. Alum dosage decreases with increase in acidity.

3. Small amounts of carbon dioxide depress the pH to a much greater extent when alkalinity is low than when high, it therefore requires more carbon dioxide to reach a definite pH than would be liberated if sulfuric acid were used. This is in accord with the fundamental law in physical chemistry which states that the ionization of a weak acid in the presence of one of its salts is inversely proportional to the amount of salt present.

4. The pH of the raw water gives no indication of the required alum dosage unless the alkalinity is also known.

5. Adjustment to a definite pH with sulfuric acid not only increases acidity but also decreases alkalinity and the maximum saving in alum is possible.

6. Adjustment to a definite pH with carbon dioxide increases the acidity but the alkalinity remains unaltered. The reduction in alum dosage is not quite as great as when sulfuric acid is used.

Slightly higher dosages than those indicated by these curves will give a larger sized floc, although Dr. G. G. Nasmith has shown that with pH adjustment of the Ottawa river water using sulfuric acid, good color removal will not be obtained unless the final pH is within the range of pH 5.1 to 5.4. This is equally true when the pH is adjusted with carbon dioxide. This optimum range would not necessarily be identical for other colored water supplies. For certain industrial uses color may not be objectionable while turbidity or iron in the turbidity may be exceptionally so. In such cases a slightly greater saving would be possible by pH adjustment than when the water is used for municipal supply purposes. Unfortunately it is the color floc which carries down the turbidity and the alum dosage can be reduced only slightly below that which will give the best color removal.

It is generally accepted that color below 10 or 15 is not apparent to the untrained observer when the water is placed in a clear glass tumbler on a white table cover. This organic coloring matter is

oxidized by chlorine or in other words, has a chlorine demand, which necessitates increased application of chlorine with possibility of taste difficulties.   Therefore, it would seem advisable to produce an effluent of as low color as possible.   Changes in the degree of color removal are reflected in changes in chlorine demand of the effluent and therefore the residual chlorine test will often indicate the necessity for minor adjustment of coagulant dosage.   Coagulation control also involves periodic bench tests to determine optimum coagulant dosage for various conditions of the raw water supply.   The relationships between these dosages and the temperature, turbidity, color, pH, alkalinity and acidity of the water can then be developed, and these tests made the basis of daily control.

Summary

In summary, the impurities in natural water supplies are to a great extent colloidal in nature and may be removed by rapid sand filtration which calls for chemical pre-treatment involving coagulation.   Alum is the coagulant most used although others are more particularly suited for certain types of water.   Good conditioning of the floc is essential, addition of hydrous silica sols having been found by Baylis to greatly improve coagulation with alum.   Colored waters are very prevalent and require special conditions for treatment, the intensity of color being variable with the pH of the water. For this type of raw supply the coagulant requirements are greatly influenced by the amounts of acidity and alkalinity present, the pH of the raw supply giving no indication of the dosage required.   Adjustment of raw water pH with sulfuric acid would result in savings in coagulant but is not recommended as it might impair public confidence in the potability of the water supply.   The effect of carbon dioxide on alum dosage is described as an item of academic interest although attention is drawn to the possibility of practical application in moderate amount to colored water of fairly low alkalinity.

Use of Sulfur Compounds for Treatment of Water and Industrial Wastes

By Lewis V. Carpenter, Lloyd R. Setter and John J. Coates

SULFUR or sulfur compounds have found rather wide application in water and sewage treatment. One of the more recent uses has been as an aid in the prevention of corrosion in industrial water systems.

A modern method of deoxygenation for corrosion prevention is the use of reducing agents to combine with the dissolved oxygen. The reaction between sodium sulfite, for example, and dissolved oxygen to form sodium sulfate is quite rapid at the temperatures found in boilers so it is extensively utilized in the deoxygenation of boiler feed water.

Powell (1) reports the use of sodium sulfite as an aid in the prevention of corrosion in a nine-mile steel pipe line carrying water to the Grand Ecaille development of The Freeport Sulphur Company. This pipe line had suffered a large loss in capacity due to tuberculation. After the pipe line had been mechanically cleaned, 95 per cent of the dissolved oxygen present in the water was removed by vacuum deaeration and the remaining 5 per cent removed by reaction with sodium sulfite. Later examinations of the pipe line indicated that the deoxygenation had been very effective in arresting corrosion.

Sulfur dioxide added as a compressed gas or generated by the use of a sulfur burner at the site has been suggested as a substitute for sodium sulfite as a reducing agent. Since the oxidation of sulfite to sulfate is quite slow at ordinary temperatures, the use of catalysts has been proposed. The results of an investigation of this subject are herein included.

Many water purification plants have adopted super-chlorination,

not only for the removal of obnoxious tastes and odors, but as a safety factor in the killing of pathogenic organisms. Naturally, it is necessary to remove the excess chlorine, and various sulfur compounds, such as sulfur dioxide, sodium sulfite, or sodium thiosulfate, have been successfully used to react with the excess chlorine and to prevent the development of chlorinous tastes in the water. Toronto, Ontario, has used sulfur dioxide successfully as a de-chlorinating agent. Glencoe, Illinois, (2) has destroyed excess chlorine by adding anhydrous sodium bisulfite through a dry feed machine. New Rochelle, New York, (3) has used sodium thiosulfate solution for the removal of excess chlorine. Hale (4) successfully overcame tastes resulting from gasoline leaching into wells by super-chlorination followed by de-chlorination with sulfur dioxide. He also used the same process to overcome tastes due to the growth of *Crenothrix* in a distribution system. Brown (5) in California also found that super-chlorination followed by sulfur dioxide treatment was most effective in controlling the growth of iron bacteria. The use of sulfur compounds for removing excess chlorine is very common, both in the United States and in foreign countries.

Sulfur compounds such as the sulfates of iron and aluminum are used successfully in the coagulation of water and sewage. Recently Schwartz (6) reported that the use of ferric sulfate and lime was the most efficient process for removing silica from water. The use of sulfur dioxide with alum for color removal is an interesting development which will be discussed later.

A patent was issued to Patrick (7) on the use of sulfur dioxide for cleaning filter sand. Patents have also been issued to Crew and Earle for cleaning sand with sulfuric acid. The advantages claimed for sulfur dioxide by the patentee are: 1. availability of sulfur dioxide at reasonable cost; 2. simplicity of application; 3. low cost of labor; 4. removal of iron and manganese and disintegration of mudballs; 5. sulfur dioxide is less dangerous to handle than caustic or sulfuric acid; 6. no removal of sand necessary.

Sulfur cements and sulfur jointing compounds are used extensively in the laying of water distribution and sewerage systems. Sulfur impregnated Portland cement concrete (8) is impervious to moisture, resistant to destructive agencies, and is said to have a higher strength than untreated concrete.

The Freeport Sulphur Company established a fellowship in the Division of Sanitary Engineering at New York University for the

study of possible uses of sulfur compounds in water and sewage treatment. During this time, some of the following ideas were studied experimentally:

1. Disinfection with sulfuryl chloride
2. Sand cleaning with sulfur dioxide
3. Color removal
4. Coagulation with sulfur compounds
5. Studies on catalysts in the oxidation of sulfite

Disinfection with Sulfuryl Chloride

Sulfuryl chloride (SO_2Cl_2) is a yellow liquid having a suffocating and irritating odor. It may be manufactured by the process in which sulfur dioxide and chlorine are continuously dissolved in a body of liquid sulfuryl chloride which carries activated carbon at room temperature. The carbon is removed from the sulfuryl chloride by filtration.

The use of sulfuryl chloride as a chlorinating agent in organic synthesis has been proposed by McKee and Salls (9). Other writers have suggested the possible use of minute quantities of sulfuryl chloride in water for the reduction of bacteria. Although sulfuryl chloride reacts with water to form acids, there existed the possibility that the compound might exert its chlorinating power upon bacteria and organic matter before it completely decomposed. A study was made of the effect of sulfuryl chloride upon the organisms normally present in water and sewage.

New York City sewage was added to tap water to give a coliform index of about 32,000 and a plate count of 3,500 per ml. on agar at 37°C. Various samples of this polluted water were treated with SO_2Cl_2 in concentrations of 5, 25, 50 and 100 p.p.m. Bacteriological samples were examined after contact periods of 0.25, 0.5 and 2.0 hours. The coliform index reduction was from 32,000 to about 7,000. The reduction seemed to be about the same for a dose of 100 p.p.m. of sulfuryl chloride as with 5 p.p.m. About the same ratio held with the plate count determinations.

It is reasonable to assume that the fact that sulfuryl chloride is immiscible in water contributed to its ineffectiveness. Although the experiments performed were not extensive enough to draw conclusions, it does seem that sulfuryl chloride does not have as great an effect on coliform organisms and the total count as might be expected from equivalent doses of chlorine. The disinfecting power

might be better realized if it were made water soluble by reaction with some other substance. In this connection, mention might be made of p-chloro-m-cresol, prepared by reacting sulfuryl chloride with m-cresol, which is said (10) to excel all other phenols in disinfecting power.
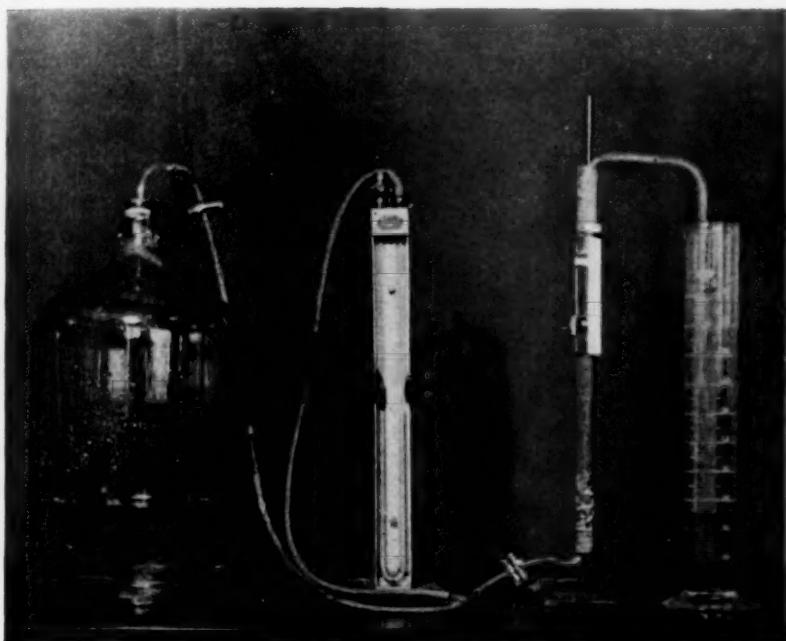
Fig. 1. Laboratory Sand Cleaning

Sand Cleaning with Sulfur Dioxide

Samples of sand were obtained from a number of filter plants so selected as to obtain sands with different kinds of coatings. Representative samples of these sands were treated in an experimental filter with measured amounts of a standard sulfur dioxide solution until visual observation indicated that all of the incrustration was removed. A separate sample of each sand was thoroughly cleaned with hydrochloric acid, and a mineral analysis made of the fixed solids removed (fig. 1). Table 1 lists the sands on the basis of grams of fixed solids removed by sulfur dioxide treatment per grams of sulfur dioxide oxidized together with a brief description of the nature

of the incrustation. These data indicate that the efficiency of the sulfur dioxide treatment is lowest for the iron-clay sands and greatest for the so-called chalk sands. Those sands containing a large percentage of manganese oxide, calcium carbonate and magnesium carbonate in the incrustation were most readily cleaned.

Color Removal

The decolorization of water through the use of sulfur dioxide both with and without a catalyst was the subject of intensive study. The color found in water supplies is generally due to the decomposition

TABLE 1

Sulfur Dioxide Treatment with Various Sands

GRAMS FIXED SOLIDS REMOVED PER GRAM OF SO_2 OXIDIZED	SAND NO.	CLASSIFICATION
0.182	4	Iron Clay
0.252	3	Iron Clay
0.258	8	Manganese Clay
0.340	5	Iron Clay
0.528	2	Iron Clay
0.841	1	Silicon
1.226	7	Manganese Clay
1.313	6	Manganese Clay
1.426	14	Manganese Clay
1.903	10	Iron oxide
8.03	12	Chalk
14.28	11	Chalk
22.25	15	Chalk
66.6	14	Chalk
111.6	13	Chalk

of vegetable matter, hence, surface waters are more highly colored than water from underground sources. The color is largely due to soluble or colloidal humins, humates and tannates. The colloidal fraction of the color usually bears a negative charge.

The decolorization of such waters may be accomplished in many ways: 1. by the decomposition of the complex to particles of such a state of dispersion that light rays may be transmitted without interference; 2. by bleaching of the color radical group; 3. by treating the color complex in such a way as to affect its surface activity in order to cause mutual flocculation of particles and render it more

amenable to coagulation by some other substance; 4. by treatment with a coagulating agent such as aluminum sulfate to cause co-pre-cipitation.   When alum is added to a colored water, dissociation occurs with the release of aluminum and sulfate ions, the formation of positively charged complexes of aluminum oxide and the formation of insoluble aluminum hydroxide.   The color colloid apparently preferentially adsorbs the positive aluminum ions and is partially neutralized by the positively charged complexes with the result that its negative charge is repressed and the forces of mass attraction become operative causing mutual coagulation of the particles. These particles then settle out or are physically dragged out of solution by the flocculant precipitate of aluminum hydroxide that has been formed.

TABLE 2

Analysis of Water Used for Color Removal Study

pH	6.6	Color (filtered)	500
Phenol Acidity	76.0 p.p.m.	Turbidity (fil.)	20
M. O. Alkalinity	160.0 p.p.m.	B. O. D. 5 day 20°C	40 p.p.m.
Total Solids	467.0 p.p.m.	Dissolved oxygen	1.0 p.p.m.
Fixed	211.0 p.p.m.	Chlorine demand	14.0 p.p.m.
Volatile	256.0 p.p.m.		

Sulfur dioxide has been used in color removal.   The Tampa, Florida, plant, as described by J. E. Lyles (11) used alum and sulfurous acid.   The latter was obtained by burning crude sulfur and dissolving the gas in water.   The water treated had a color of 200 p.p.m. at certain seasons of the year.   With sulfurous acid being used, the amount of alum required was greatly reduced and economies realized.   It was used to reduce the raw water alkalinity to the proper point for color removal with the aid of alum.

A sample of synthetic water was prepared in the laboratory by steeping fresh oak leaves in water.   In a month a highly colored water was produced but the large quantity of hydrogen sulfide present necessitated aeration for several days.   A partial analysis of this water after three months' storage is given in table 2.

Most of the studies were made after this water had been diluted volume for volume with tap water with a resultant color of 250 p.p.m.   The experimentation was begun by treating the sample with alum varying in dosage from 1 to 15 grains per gallon.   The

optimum dose was about 11 grains per gallon which reduced the color from 250 p.p.m. to 25 p.p.m. with a resultant pH of 5.85. The addition of lime to the decolorized supernatant did not cause a return of the color. Alum treatment would not reduce the color below 25 p.p.m.

The water was next treated with sulfur dioxide in doses of 1 to 12 grains per gallon. Although a color reduction from 250 to 130 p.p.m. was obtained upon the addition of 9 grains per gallon of sulfur dioxide, the process was quite inefficient in that only about 15 per cent of the
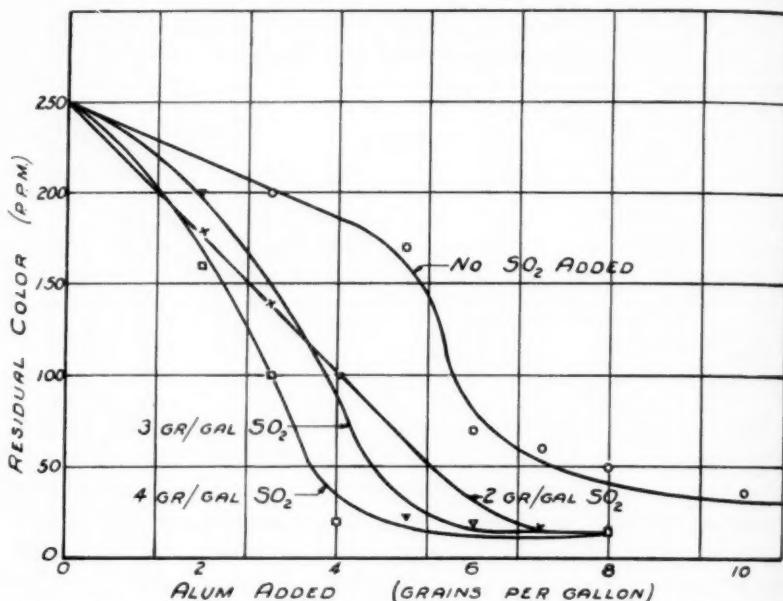
FIG. 2. Effect of Sulfur Dioxide and Alum Dosages on Residual Color

added sulfur dioxide was oxidized. Also, the reduction of color by sulfur dioxide was quite temporary, since alkalinization of the samples with lime restored the color to nearly its original value.

The effect of treating water for the removal of color by the addition of alum and sulfur dioxide is recorded graphically in fig. 2. It is to be noted that the best color reduction occurred at pH 4.5 with a dose of 2 grains per gallon of sulfur dioxide and 7 grains per gallon of alum as compared with 11 grains per gallon of alum alone. Also, the residual color was less in the former case.

Table 3 is a summation of the data obtained indicating the best color removal with each process studied and the chemical dosages necessary.   In those cases where a coagulant was added, the solution was mechanically flocculated for a period of fifteen minutes.   A quiescent settling period of thirty minutes then preceded sampling. All pH measurements were made potentiometrically.

The isoelectric point for most of the compounds imparting a color to water is at a relatively low pH value.   For this reason, decolorization is usually most effective when carried out in the acid pH range.

TABLE 3
Summary of Color Removal Data

METHOD OF TREATMENT	ALUM ADDED	SO₂ ADDED	SO₂ CONTACT TIME	% SO₂ OXIDIZED	pH		ALKAL.		COLOR	
					Raw	Treat	Raw	Treat	Raw	Treat
	$Gr./Gal.$	$Gr./Gal.$	$hr.$				$p.p.m.$	$p.p.m.$		
Alum and SO$_2$	7	2	—	95	7.25	4.5	86	a	250	15
No Contact Time	6	4	—	54	7.20	3.70	88	a	250	15
Alum and SO$_2$ in the	7.5	0.78	0.5	95	7.5	6.3	140	43	250	15
presence of 2	6.0	1.52	0.5	97	7.5	5.8	142	18	250	15
p.p.m. Mn++										
Alum and SO$_2$ with	8	2	0.75	79	7.3	6.15	95	26	250	20
SO$_2$ allowed con-	8	2	3.0	85	7.3	6.05	95	16	250	20
tact time	7	2	2.5	80	7.3	6.3	95	24	250	20
	7	2	5.0	80	7.3	5.75	95	14	250	20
	5	4	0.75	89	7.4	3.9	100	a	250	20
	5	4	2.0	89	7.4	3.75	100	a	250	20
Alum Alone	11.0	—	—	—	7.3	5.9	88	26	250	25

Note *a* indicates presence of mineral acidity.

To reach the so-called optimum pH, especially in an alkaline or buffered water, necessitates additional chemicals over the amount required to precipitate the coloring matter.   Where the primary coagulant is relatively costly, economies are frequently effected by the addition of an acid with the coagulant.

Two runs are reported in which 2 p.p.m. of manganese as manganous sulfate were added to the alum-SO$_2$ treated samples in an attempt to catalyze the oxidation of the sulfur dioxide.   The results of this treatment were the best obtained by any process, 6 grains per gallon of alum plus 1.62 grains per gallon of sulfur dioxide reducing the color

from 250 to 15 p.p.m., with almost complete oxidation of the sulfur dioxide. It is not quite clear as to whether the manganese catalyzed a reaction between the sulfur dioxide and the organic matter to give colorless compounds or catalyzed the reaction between the sulfur dioxide and dissolved oxygen to give sulfuric acid or whether a combination of the two reactions took place. In any case, the results indicate that the value of the sulfur dioxide is most fully realized when it is most completely oxidized.
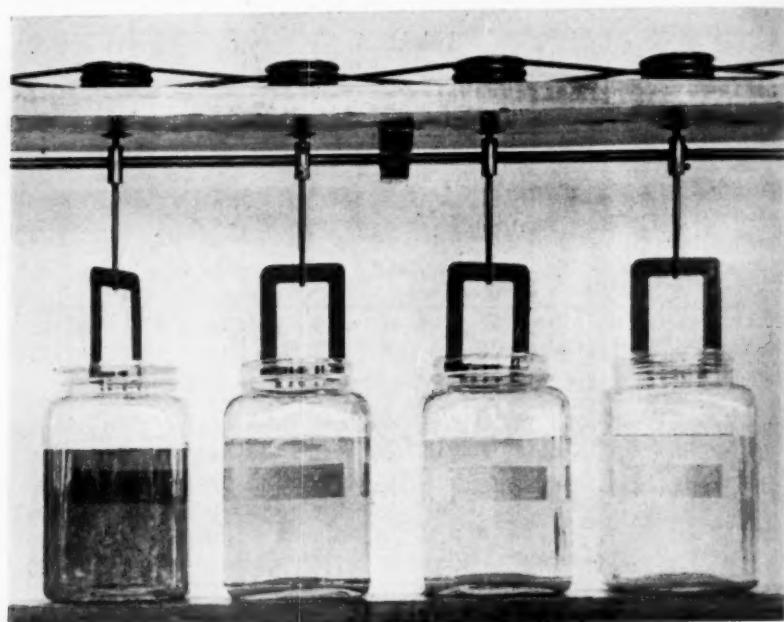
Fig. 3. Coagulation for Color Removal

Experiments were made to determine whether or not the sulfur dioxide contact time had any effect on the removal of color. The sulfur dioxide doses used were 2 and 4 grains per gallon and contact periods of from 1 to 5 hours were allowed before the addition of alum. The data are sufficient to show that allowing the sulfur dioxide a contact time up to 5 hours before the addition of alum has little effect on the reduction of color.

Using the same synthetic colored water, but undiluted, a series of tests was made using copperas and chlorinated copperas as the co-

agulants.   Copperas in doses up to 70 p.p.m. $Fe++$ gave practically no color reduction.   However, the addition of 3.8 grains per gallon $Fe+++$, added as chlorinated copperas, reduced the color from 500 to 25 p.p.m.   This amount of ferric iron corresponds to the addition of 10.3 grains per gallon of ferrous sulfate plus 2.4 grains per gallon of chlorine.

In order to compare the action of an oxidizing and a reducing agent, experiments were performed using chlorine and sulfur dioxide. The chlorine exerted a strong bleaching effect upon the color when large doses were used, 10 grains per gallon reducing the color from 500 to 15 p.p.m. after a 45-minute contact time.   Ten grains per gallon of sulfur dioxide lowered the color to only 300 p.p.m.   Similar experiments were made on the diluted water with 8 grains per gallon of chlorine reducing the color from 250 to 10 p.p.m. and 8 grains per gallon of sulfur dioxide reducing the color to 150 p.p.m.   As was also true of sulfur dioxide, chlorination did not give a permanent color removal since the color returned upon the addition of alkali.

Experiments with alum and chlorine for color removal indicated that the value of this process is questionable in view of the high doses required and the excessive chlorine residual.

Experiments made on a natural water having a color of 45 p.p.m. indicated that the addition of small amounts of sulfur dioxide effected a saving in the amount of alum required for decolorization.   To reduce the color to 10 p.p.m., 20 p.p.m. of alum alone were required. With the addition of 3 p.p.m. of sulfur dioxide, the alum dose was reduced to 12 p.p.m.

Coagulation with Sulfur Compounds

Many plants find it to their advantage to add an acid to the water to lower the pH for coagulation.   Sulfur dioxide prepared by burning crude sulfur or added from cylinders has been of particular value.

Ferric sulfate as a coagulant has recently been made commercially available to the water and sewage field.   It is particularly adaptable to the treatment of water and sewage because of its wide coagulating range and because it forms a heavy, bulky floc.   Depending largely on the substances to be treated, the coagulating range for ferric sulfate may extend from pH 4.0 to 9.0.

In the field of water purification, ferric sulfate has been of value in the removal of manganese, color, and silica.   Craig (12) found that ferric sulfate was very valuable in the coagulation of a soft water

containing iron and manganese. Schwartz (6) investigating methods of removal of silica from water, found that coagulation with ferric sulfate on the alkaline side gave the best removal. Residual silica concentrations as low as 2.2 p.p.m. were obtained when the water was coagulated with 75 p.p.m. $Fe_2(SO_4)_3$ at a pH of 8.5–9.5. When this process for silica removal was transferred from the experimental to a plant scale, excellent removal was obtained by the application of from 25 to 50 p.p.m. $Fe_2(SO_4)_3$.

Ferric sulfate may be prepared at the point of use by the interaction of scrap iron or ferrous sulfate, sulfur dioxide, air and water. The
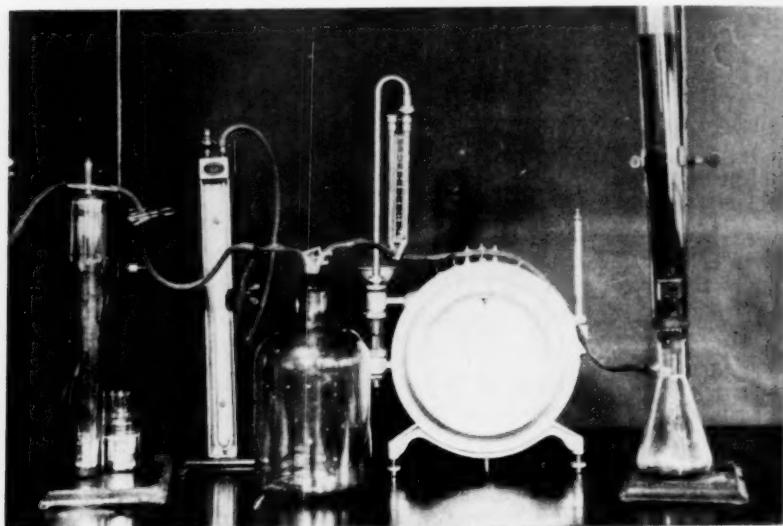
FIG. 4. Laboratory Preparation of Ferric Sulfate

development of this process has been largely the result of the work of Wartman and Keyes (13) and Lyles (14). A number of laboratory investigations of this process have been made. In table 4 are compiled the data from seven runs made during this investigation. A ferrous sulfate solution was used as the source of iron.

With an initial ferrous iron concentration of approximately 5,000 p.p.m. (90 m mol/1), from 75 to 90 per cent will be oxidized in 90 minutes with SO_2/air ratios of 0.0071 to 0.0142. The product will also contain from 20 to 120 m mol/1 of free sulfuric acid. An SO_2/air ratio of 0.0125 may be expected, after 90 minutes treatment at a gas

rate of approximately **3,000** ml./min., to give a product containing approximately **75** m mol/liter of ferric iron and **75** m mol/liter of free sulfuric acid. Such a product will represent approximately **65** per cent utilization of the added sulfur dioxide.

The rate of oxidation of the ferrous iron decreases after about **60** minutes treatment with an SO_2/air ratio of 0.0142 and after a longer period with lesser ratios. No appreciable production of sulfuric acid will occur until the rate of iron oxidation decreases.

The large quantities of free sulfuric acid formed, particularly with high SO_2/air ratios, may tend to limit the usefulness of the prepared ferric sulfate as a coagulant to those cases where coagulation may be carried out at a low pH.

TABLE 4

Data from Seven Runs

RUN	% SO_2 IN GAS MIXTURE	TOTAL REAC-TION TIME	FERRIC IRON	TOTAL IRON	FREE H_2SO_4	% OXI-DATION Fe++ TO Fe+++	% SO_2 ADDED FORMING $Fe_2(SO_4)_3$	% SO_2 ADDED FORMING H_2SO_4	RATIO m mol Fe m mol H_2SO_4
	%	min.	m mol/l	m mol/l	m mol/l	%	%	%	
1	0.71	90	64.6	99.4	21.7	65.0	22.6	15.2	2.98
2	1.42	90	87.3	95.8	120.3	91.2	19.05	52.5	0.725
3	1.06	90	72.1	94.4	38.0	76.5	19.0	19.9	1.90
4*	0.77	90	76.4	99 7	53.7	76.6	27.5	31.4	1.75
5	1.20	90	82.9	98.0	76.6	84.6	19.6	36.2	1.08
6	1.46	90	64.4	160.5	16.4	40.1	11.8	6.0	3.92
7	0.71	90	78.5	177.0	4.6	44.3	28.6	3.1	17.0

* 10 p.p.m. Mn++ added.

The addition of small amounts of manganese to the reaction tower allows the use of lower SO_2/air ratios and results in an increased utilization of the added sulfur dioxide.

It was found that, if the initial iron concentration is doubled, approximately twice the reaction time will be required for oxidation. The efficiency of sulfur dioxide utilization is also lower with increased iron concentrations.

It is very important that the gas mixture be passed through the iron solution in the form of very small bubbles. In the experiments herein reported, the loss of head through the diffuser necessary for good aeration was about 3.5 times the static head in the tower.

Catalysts in the Oxidation of Sulfur Dioxide

The literature on the catalytic oxidation of sulfur dioxide by oxygen in aqueous solution at low temperatures is rather meager. Rice (15) found that nitrogen compounds of inorganic salts, rare metal chlorides, manganous sulfate, iron sulfate and copper sulfate were quite effective in increasing the rapidity with which sulfur compounds are oxidized to sulfates through the absorption of oxygen. Titoff (16) found that even traces of iron and copper acted as positive catalysts.

A number of experiments were made to clarify these results further and to determine the minimum density of catalyst and the effect of contact time and pH upon the reaction.

Preliminary experimentation with a number of substances indicated that manganous manganese, ferrous iron and cupric copper offered the greatest possibilities.

The procedure consisted of siphoning aerated city tap water containing the desired amount of catalyst into 250 ml. bottles in such a way as to prevent air entrainment. The dissolved oxygen was determined in two bottles and an amount of sulfurous acid, equal to 101 to 102 per cent of the amount necessary to deplete the dissolved oxygen content, was added to the remaining bottles by means of a pipette lowered well into the bottle. The bottles were then stoppered, shaken, and allowed to stand for varying contact periods.

At the end of the desired time, the entire contents of the storage bottle were transferred to a flask and titrated with a standard iodine solution. The iodine consumption was considered equivalent to the sulfurous acid remaining.

Table 5 indicates the effect of contact time and concentration of the three catalysts. It is evident that manganous manganese was the most effective of the metals studied with iron and copper following in that order.

The reaction between sulfur dioxide and dissolved oxygen in an acid solution at ordinary temperatures (17–19°C.) was found to be very slow. Less than 14 per cent of the sulfur dioxide was oxidized in 30 minutes. The original pH of the water was 7.2–7.6. If the original pH was lowered to 6.0 with hydrochloric acid, less than 5 per cent of the sulfur dioxide was oxidized in 30 minutes, while if the original pH was raised to 10.3, the percentage of sulfur dioxide oxidized in 30 minutes was 60.0. These results indicate the major

effect of hydrogen ion concentrations on the velocity of sulfur dioxide oxidation in the absence of added catalysts.

The manganous sulfate has positive catalytic powers in the oxidation of sulfur dioxide at a final pH of 2.9–3.2.   The results indicate that the quantity of sulfur dioxide oxidized in 15 minutes is doubled with the addition of only 0.1 p.p.m. Mn++, or with the addition of 0.5 p.p.m. Mn++ the reduction of the available dissolved oxygen

TABLE 5

Percentage of Added Sulfur Dioxide Oxidized in Presence of Catalysts

CATALYST		TIME OF CONTACT			
Kind	Cation	5 minutes	10 minutes	15 minutes	30 minutes
	p.p.m.				
None		Trace	0.3	7.0	13.6
$MnSO_4$	0.1	3.9	7.2	14.2	19.7
	0.3	10.7	19.1	26.0	50.2
	0.5	16.3	42.4	68.0	97.2
	1.0	57.0	95.1	97.8	94.9
	2.0	95.1	98.5	98.5	99.3
$CuSO_4$	0.5	5.2	6.7	6.7	22.2
	1.0	3.7	3.7	3.0	8.2
	2.0	4.5	8.2	6.7	12.9
	4.0			6.7	11.0
	8.0			7.6	17.6
	12.0			14.5	36.9
$FeSO_4$	0.1	1.0	6.0	9.0	24.2
	0.3	2.4	5.3	14.0	30.8
	0.5	12.2	17.3	24	55.8
	1.0	19.2	26.1	33.7	71.2
	2.0	42.3	48.1	64.0	91.4
	4.0			95.4	94.4

is virtually complete in 30 minutes.   Greater quantities of manganese catalyst served to complete the oxidation of sulfur dioxide or reduction of dissolved oxygen in a shorter period of time.   Thus, 2.0 p.p.m. Mn++ produced complete reduction of dissolved oxygen in less than 10 minutes.

Somewhat greater concentrations of $FeSO_4$ than $MnSO_4$ were necessary to produce positive catalytic effects. Thus, 2.0 p.p.m. $FeSO_4$-Fe was as effective as 0.5 p.p.m. $MnSO_4$-Mn.

Copper sulfate in concentrations of 0.5 to 8.0 p.p.m. Cu++ appears to have little influence on the rate of sulfur dioxide oxidation. A dose of 12.0 p.p.m. CuSO₄-Cu indicated a positive catalytic effect.

The more pertinent data of table 5 are presented in fig. 5 in which the theoretical dissolved oxygen values have been calculated from the sulfur dioxide consumed in unit time as decreasing the original dissolved oxygen concentration.

The experimentation was repeated on city tap water (total al-
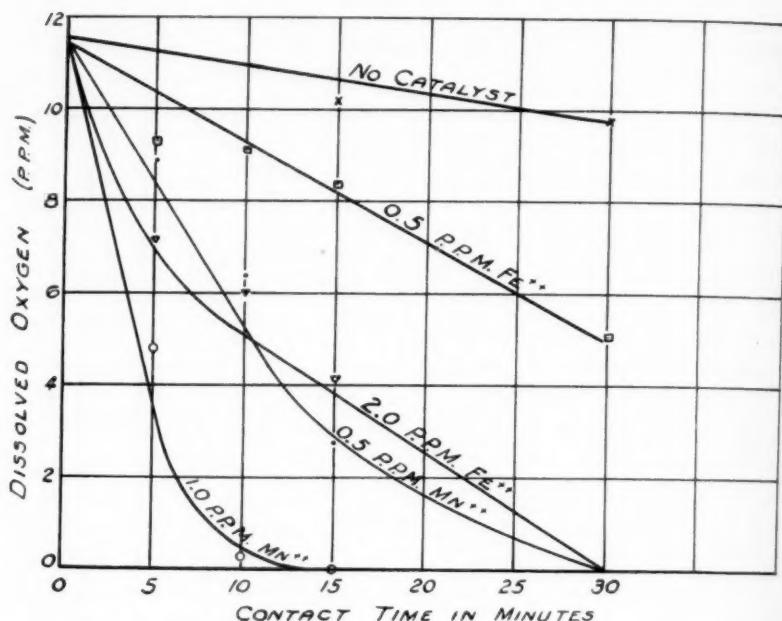
Fig. 5. Effect of Sulfur Dioxide with Catalysts on the Reduction of Dissolved Oxygen

kalinity 25 p.p.m. CaCO₃) the pH of which was first adjusted to 6.0 with hydrochloric acid and 10.2 with hydrated lime.

An insignificant retardation in the rate of deoxygenation occurred in the presence of a given quantity of catalyst when the water was first adjusted to pH 6.0.

Increasing the pH to 10.2, which likewise increased the total alkalinity, caused a substantial increase in the effectiveness of the manganese catalyst but had a retarding effect on the copper and

iron catalysts. One half p.p.m. $MnSO_4$-Mn caused complete deoxygenation in less than 10 minutes at original pH 10.2, whereas 30 minutes were required for water of original pH 7.2.

Summary

The effect of sulfuryl chloride upon sewage organisms was studied and it was found that in doses of from 5 to 100 p.p.m., sulfuryl chloride gave an average coliform index reduction of from 32,000 to 7,000 with contact periods up to 2 hours. All doses gave bacterial reductions appreciably lower than would be obtained from equivalent doses of chlorine.

Sand cleaning with sulfur dioxide was investigated and it was found that those sands containing a large percentage of manganese oxide, calcium carbonate and magnesium carbonate in the incrustants were most readily cleaned.

A number of experiments have been made to determine the value of sulfur dioxide in the coagulation of colored waters. It was found that the addition of relatively small quantities of sulfur dioxide allowed a considerable saving in the amount of coagulant required. The relationship between alum and sulfur dioxide doses necessary to decolorize a synthetic water is given in fig. 2.

A number of investigations have been made of the preparation of ferric sulfate by the interaction of ferrous sulfate, sulfur dioxide, air and water. This reaction is most efficient with a ratio of sulfur dioxide to air of about 0.0125. With such a ratio, from 60 to 90 minutes reaction, at a gas rate of approximately 3,000 ml./min. will effect about 80 per cent oxidation of an 0.5 per cent iron solution with the simultaneous production of about 75 m mol/liter of sulfuric acid.

The oxidation of sulfurous acid by dissolved oxygen was studied and it was found that the addition of small amounts of manganous manganese and ferrous iron will greatly catalyze this reaction. The addition of 1.0 p.p.m. manganous ion resulted in the reaction being 98 per cent complete in fifteen minutes at a final pH of about 3.0. The reaction in the absence of a catalyst was little more than 20 per cent complete in thirty minutes.

by D. B. Mason, Technical Director, Freeport Sulphur Company, and Sheppard T. Powell, Consulting Engineer.

References

1. POWELL, S. T., AND BURNS, H. S. Vacuum Deaeration Combats Cold Water Corrosion. Chem. Met. Eng., 4: 180 (1936).
2. PFLANZ, E. L. Super and Dechlorination at Glencoe, Ill. W. W. and Sew., 79: 93 (1932).
3. ENSLOW, L. H. Chlorination of Water Without Taste Production. Proc., Short Course at Univ. of So. California, 193 (1930).
4. HALE, F. E. Successful Superchlorination and Dechlorination for Medicinal Taste of a Well Supply. Jour. A. W. W. A., 23: 375 (1931).
5. BROWN, K. W. Occurrence and Control of Iron Bacteria in Water Supplies. Jour. A. W. W. A., 26: 1684 (1934).
6. SCHWARTZ, M. C. The Removal of Silica from Water. Jour. A. W. W. A., 30: 551 (1938).
7. PATRICK, J. G. Method of Cleaning Sand Filters and Appurtenances. U. S. Patent 2,069,621 to West Virginia Pulp & Paper Co.
8. CUNNINGHAM, W. A. Sulphur. Jour. Chem. Education, 12: 17, 83, 120 (1935).
9. McKEE, R. H., AND SALLS, C. M. Sulfuryl Chloride. Ind. Eng. Chem., 16: 279 (1924).
10. ULLMAN, F. Enzyklopadie der Technischen Chemie, 3: 329 (1929).
11. LYLES, J. E. Manufacture, Use and Control of Acid at Tampa, Fla., Water Purification Plant. Jour. A. W. W. A., 26: 1214 (1934).
12. CRAIG, E. C., AND BEAN, H. C. Ferric Iron Coagulation of Soft Water. W. W. and Sew., 79: 30 (1932).
13. WARTMAN, F. S., AND KEYES, H. E. Development of Some Fundamentals in the Ferric Sulphate-Sulphuric Acid Process. R. I. 2839, Dept. Commerce, U. S. Bureau of Mines.
14. LYLES, J. E. The Sulfanation Process. A private communication (1939).
15. RICE, C. W. Unusual Boiler Problems Caused by Corrosion. Combustion, 8: 31 (1936).
16. TITOFF, A. Zeitschrift fur Physicalische Chemie, 45: 641 (1903).

ABSTRACTS OF WATER WORKS LITERATURE

Key. **30:** 402 (Mar. '38) indicates volume 30, page 402, issue dated March 1938. If the publication is paged by issues, **30:** 3: 402 (Mar. '38) indicates volume 30, number 3, page 402. Material inclosed in starred brackets, ★[ ]★, is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; P. H. E. A.—Public Health Engineering Abstracts; W. P. R.—Water Pollution Research (British).*

WATER QUALITY AND ANALYSIS

Metropolitan Water Board, London, Eng. Thirty-Second Annual Report. Results of Chemical and Bacteriological Examinations. 1937. C. H. H. HAROLD. Records death of director Lt.-Col. Harold on July 19, '38. *Introduction:* Effort is made to briefly review basic principles on which bacterial water analysis based, giving reasons for belief that results achieved provide security. Prolonged investigations in previous yrs. in Board's labs., involving critical exam. of dejecta of man, beast, bird and fish, left no doubt that since the bacterial indicator group of pollution (coli-aerogenes) do not arise of themselves their presence denotes the existence of pollution of animal origin, hence precautionary measures are indicated. While *Esch. coli* is identified on certain standard characteristics, being a living entity, certain variability of its attributes must be expected. Noted that poor lactose fractors more usually derived from less polluted sources and rapid and brisk gas production normally associated with more recent pollution. While presence of occasional coliforms in certain supplies has little epidemiological significance, their presence indicates connection with excretory pollution; would therefore appear unwise not to regard their presence even in 100 ml. with more than suspicion, since not possible to define origin or path of pollution. No person has right to define how near a population may be brought to infection, when exclusion by relatively inexpensive means is readily available. Conveyance of infection by water may be described as summation of coincidences, and reason for absence of infection at times, even in presence of *Esch. coli*, is that vital factor —the infective person—has not been within the path. Felt that delivery of standard supply on a coli basis negative in 100 ml. has much to commend it. *Bacteriological Section:* Bacterial analytical control methods must be rapid and trustworthy. A false presumptive result is evidence of fallacy in method; may be defined as production of acid and gas in lactose medium by organisms other than members of coli-aerogenes group. May be due to several types, among them: (1) spore bearing lactose fermenting aerobes and anaerobes; and (2) to symbiotic action, in which first there is a splitting of lactose

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and subsequent fermentation of glucose by proteus-like organisms. Isolation of glucose fermenters in absence of coli-aerogenes types held of great value in early detection of pollution. MacConkey broth (containing bile salt and litmus and incubated at 42°C.) used for past 32 yrs. satisfactorily as primary enrichment medium for isolation of coliforms, giving only about 5–10% false presumptives. Comparative tests carried out in '37, using brilliant green bile (B.G.B.) and methylene blue-brom-cresol-purple (Dominick-Lauter) broths. Each medium found almost equally sensitive in demonstrating coliform bacteria. MacConkey broth proved superior in cases of stored waters, typical of Board's supplies. Slight advantage in favor of B.G.B. in filtered waters; glucose fermenting type of false presumptive is not inhibited by B.G.B., fewer obtained with MacConkey and inhibited by Dominick-Lauter; spore-bearing lactose fermenters suppressed almost completely by B.G.B. and D–L. with MacConkey media also exerting strong inhibitory powers. B.G.B. better than D–L. as support for standard MacConkey. Indol production used as routine until spring '38, change then made to B.G.B. in routine, because known number of indol-producing tubes increased when water temp. reached 10°–12°C., probably due to naturally occurring indol-producing organism being able to multiply in water at these temps. and so introduce an error in test. Citrate solution introduced into routine because now generally recognized that there exists an indol negative variety of *Esch. coli*, and that some indol producing lactose fermenters are not *Esch. coli* but intermediates, *Aer. aerogenes* or *Bact. cloacae*. Differentiates *Esch. coli* from atypical forms. Has continued to give satisfactory results confirming previous exptl. work and has demonstrated increase in atypical forms common in summer months. Tables given showing classification of positives into various groups. *Biological Section:* Treatment of res. waters guided not only by algae present but also by chemical character of water. From Jan. 30 to May 14, '37 continuous dose of $CuSO_4$ applied to incoming water to Queen Mary Res. On May 14, even though *Fragilaria* still abundant and "resistance to filtration" was only 15 (a low figure indicating water hard to filter), $CuSO_4$ cut out because steady fall of phosphate conc. had indicated cessation of spring algal max. was imminent. Within 8 days resistance to filtration had jumped to 318 indicating a very marked falling off in numbers of algae, a fact confirmed by microscopical exam. Discussion given in considerable detail of nitrogen, phosphate and SiO_2 changes in used and unused res. waters. Organisms living in water are dependent upon a complex of factors, and that factor which is present in, or can be reduced to, minimal amounts determines conditions of successful or continual development. Enables forecast of events; for example when SiO_2 and P_2O_5 fall to min., can be quite certain period of diatom development is at end. Appears nitrogen is limiting factor in the London res.'s in use. *Chemical Section:* Routine analysis for phosphates and silica on all waters started. Results with new photo-electric turbidimeter, described in '36 report, now expressed in parts of silica per 100,000 instead of saccharated carbonate of iron, ratio of latter to former being about 1.1 to 1. Silica standard of 0.5 parts per 100,000 seems reasonable and useful standard figure for filtered waters. Exptl. work on cleaning filter sand encrusted with $CaCO_3$, together with efforts to find cause, described. Test for small amts.

Cu given: To 50 ml. of sample add 1 ml. of 5 N acetic acid and 0.5 ml. of 0.06% rubeanic acid in absolute alcohol. Cu not read before elapse of at least 10 min. Standards made in same manner from $CuSO_4$ soln. of known strength. *Works Efficiency:* '37 first complete yr. during which terminal chloramination practiced, resulted in remarkable figure of 99.0% first-class samples (coliforms absent in 100 ml. water) for the whole of the London supply. If unchloraminated wells excluded, figure of 99.4% first-class samples obtained. Statistics given for various purification works. *Meteorological Notes:* Rainfall given by months for 7 locations, equalled 25.58″ for yr. in Camden Square, London, compared to 1881–1915 av. of 24.47″. ★[This report continues to be one of the most interesting and informative of water works publications. The included material, comprising a record of routine laboratory work and the results of scientific research, indicates the important role the sciences of chemistry, biology and bacteriology can play in the solution of the complex problems of water supply and treatment]★.—*Martin E. Flentje.*

Improving the Bacterial Quality of Water. JOHN R. BAYLIS. W. W. and Sew. **86**: 96 (Mar. '39). Author believes present bacterial standards of water quality are insufficient and that further efforts should be made to improve quality. Suggests and recommends adoption of methods of treatment and new standards to meet challenge of health authorities who are attributing disease outbreaks to the water supply if the disease can be water-borne and if the outbreak cannot be accounted for as coming from some other source. As long as it is known that present treatments do not remove all bacteria, question will remain if transmission of disease also not possible. Suggested standard includes almost complete elimination from finished water of positive presumptive gas-forming bacteria on lactose or any other sugar broth, with prompt attention being given to treatment being applied if within period of 1 mo. more than 1% of 10 ml. tubes, or more than 10% of 100 ml. tubes show gas. Total count at 37°C. should av. not more than 2 per ml. Treatment should be increased when, on 2 consecutive days or 3 days in 1 week, 100% of 100 ml. or more than 10% of 10 ml. tubes of finished water show presence of gas. In small plants at least 10–10 ml. tubes of finished water should be innoculated daily, with at least 2 samples collected 12 hrs. apart; in larger plants at least 40–10 ml. tubes and sample collection at 4 hr. intervals. In cities of over 25,000 pop. at least 5 daily dist. system samples should be collected, and from 10 points in cities over 500,000; two to three daily samples sufficient in small cities, with at least 2 of samples from outer extremities of dist. system where believed water longest in system. All water containing sewage pollution should be chlorinated to at least 0.5 p.p.m. residual chlorine after 2 hrs. retention of water, with at least 1.0 p.p.m., where there is considerable pollution. Raw water best place to add high chlorine dose, leaving possibility for later corrective treatment if necessary. Chlorine resistant bacteria, some of which form gas in lactose broth, should be eliminated. Where water is polluted, it should remain in plant 24 hrs. before being sent to dist. system. Believes more time should be spent on trying to eliminate all bacteria in water and less on trying to prove certain types of gas-forming organisms do or do not belong to coliform group.—*Martin E. Flentje.*

Some Popular Misconceptions Concerning the Function, Value and Significance of Water Analyses. CHARLES D. HOWARD. Health News, N. H. State Board of Board of Health **17**: No. 2 (Feb. '39). A common-sense exposition of what water analysis does and does not reveal. Based on experience gained in total of 65,000 water analyses made since inception of N. H. Lab. of Hygiene with several thousand yearly analyses at present time. Reports on water analyses based on (1) the relatively simple analysis proper and (2) far from simple interpretation of significance of all data including analytical results and information as to identity, location, character of source and associated conditions. Sanitary survey needed to make analytical results of value. Presence of excessive chlorides is apt to indicate sink drain seepage, but may be due to salt dumpage into well, "thawing out" of frozen well, use of $CaCl_2$ on nearby road, etc. Nitrate excess similarly usually attributed to seepage from privy, cesspool, barnyard or manured soil but may be due to fertilizer (nitrate of soda) on nearby garden. Analysis only indicative of water character at time of sampling; for this reason inspection of location to show potential hazards important. Bacteriological analysis extremely important but not supreme, it is indispensable, but the facts are (1) that the sanitary inspection is of equal or even greater importance, and (2) that while a positive finding is a definite danger signal, a negative bacteriological finding given by a single sample affords no guaranty of safety. Two members of colon-aerogenes group generally recognized, fecal and nonfecal types, usually no effort made to differentiate between them. Up to present time not feasible to distinguish coli of human origin from those contained in animal excretions, hence "positive" finding is by no means to be accepted as evidence of contamination of human origin. In ground waters chemical and bacteriological analyses both of importance. Believed rural wells do not today deserve reputation as cause of typhoid; flies and open privy vaults more likely than the farm well to be the responsible agents of transmission. Possible fallacy pointed out in placing emphasis upon results of a bacteriological water analysis where a typhoid case is encountered, analysis should not be omitted but imperative that search be made for actual causative agent, meaning a prior case of typhoid or a food-handling "carrier". For most part both routine chemical and bacteriological analyses show contamination, but do not prove infection. Both methods of analysis have distinct limitations, do however supplement each other.—*Martin E. Flentje.*

The Bacteriological Examination of Drinking Water in Victoria (Australia). N. ATKINSON AND E. J. F. WOOD. Proc. roy. Soc. Vict. **50**: 244 ('38). Contains recommendations for a standard routine method for examination of drinking water in Victoria. Since most of the water is obtained from catchment areas free from human pollution, special treatment such as filtration or chlorination is seldom applied. In consequence, the bacterial counts may be relatively high; the presence of coli-aerogenes organisms is, however, not significant, since they are not of human origin. Results of tests should be studied in conjunction with conditions prevailing in the watersheds at time of sampling. Recommendations include methods of sampling and labelling, and technic of making plate counts, and presumptive and confirmatory tests

for *Esch. coli;* expression of results and significance of false positive reactions are discussed.　The laboratory procedure suggested is summarized.—*W. P. R.*

Matters to be Observed in Sampling and Testing of Water. RICHARD SCHMIDT. Gas-u. Wasser **82**: 135 (Feb. 25, '39).　Testing of water samples gives dependable results only if the samples are collected properly.　Sterile containers must be used for samples for bacteriological tests.　The sampling outlet should be flamed and the water run for some time.　New wells should only be tested after several days pumping and filter effluents should not be tested immediately after washing the filter.　Samples for bacteriological test should be examined immediately after sampling.　Samples for chemical analysis should be taken in clean, clear bottles of 1 to 1½ liters.　The water should be left running for a while before taking the sample.　The bottle should be filled completely and through a rubber hose that reaches to its bottom, to allow determination of free CO_2.　Dissolved oxygen and H_2S can only be determined in the field.　Generally more taps for sampling are needed in water works.　It should not only be possible to sample from each step in the treatment, but also from each filter unit.　Samples to be tested for lead require special treatment.　They should be taken from a tap after standing from 12–14 hours in the pipe and be acidified with several ml. of acetic acid per liter to hinder adsorption of lead by the glass.　Chemical analysis generally tests for the hygienic characteristics, but gives very little information on the corrosive properties of the water.　Tests recommended are pH, NH_4, NO_2^-, NO_3^-, Cl^-, Fe, Mn, oxygen consumed, free CO_2, bound CO_2, total hardness, carbonate hardness, and alkalinity.　As a rule determinations of Ca^{++}, Mg^{++} and SO_4^{--} are not necessary.　Tests should be made according to standard methods by a laboratory experienced in water analysis.—*Max Suter.*

A Criticism of the Hygienic Examination of Drinking Water on the Basis of a Large Number of Analyses from Schleswig-Holstein. H. THIELE AND M. PEHRS. Arch. f. Hyg. u. Bakt. (Ger.) **121**: 143 ('38).　The bacteriological and chemical analyses of about 900 waters were examined to determine whether there is correlation between the results of the two types of analysis.　In 23.2% the water was passed as safe by both analyses.　In 87.2% the chemical analysis was unsatisfactory, whereas in 38.6% the bacteriological analysis revealed the probable presence of dangerous pollution.　Only in 28.5% did chemical and bacteriological analyses agree in condemning a supply.　Although the great majority of waters which are dangerous are discovered by chemical or bacteriological analysis, it is urged that the local conditions of collection should always be studied, and if found unsatisfactory such waters should be condemned, even if the analyses are satisfactory.—*B. H.*

New Swiss Regulations for Drinking and Mineral Waters. H. MOHLER. Monatsbulletin (Swiss) **18**: 193 (Sept. '38).　New regulations include max. chem. content of the following in mg./liter respectively: oxygen demand ($KMnO_4$)—6, free NH_3—0.02, albuminoid NH_3—0.05, nitrite—0, nitrate NO_3—20, chloride Cl—10.　Residual chlorine values below 0.15 mg./liter to be detn'd. with o'tolidine, over 0.15 mg./liter by starch-iodide method.　To prevent

taste, water should not contain over 0.05 mg./liter residual Cl. Presence of coliform bacteria detn'd. by use of dextrose-neutral red agar, lactose broth at 37°C. and mannitol broth at 43°C. Method for detn. of aerogenes also set up. Limits for (1) bacterial count and (2) typical coliforms for various waters set up, being for spring water, ground water and treated waters, respectively, as follows: (1) not over 100, (2) absent in 20 cc.; (1) under 10, (2) absent in 100 cc.; (1) under 10, (2) not demonstrable. Considerable information given regarding methods of classifying medicinal and mineral waters among classes being:—natural waters containing Ca salts, alkali, strontium, lithium waters etc. Also gives limits of main constituent in each class. Typical analysis of mineral water with explanation of findings given.—*Martin E. Flentje.*

Laboratory Control Used by Pasadena Department. FRANK E. MARKS AND EARL J. LYNDE. W. W. Eng. **92**: 309 (Mar. 15, '39). Necessity for lab. control of water supply early recognized by Pasadena, Calif. water dep't. Pop. of 100,000 served with av. of 13.3 m.g.d., 86% of which comes from surface supplies and 14% from wells. 72% of surface water comes from 12,000 mil. gal. Morris Res., 20 mi. east of city. Dep't's own lab. handles all but bact. tests, these made by Health Dep't. Approx. 2000 yearly water samples collected. One hundred samples per mo., taken twice weekly from Morris Res. for microscopical exam., in addition similar samples taken from main dist. system reservoirs. Daily Cl residual, pH, CO_2, alk., turb., temp., and hardness detn'd. on system samples. Written reports of water quality made weekly. Acid water constantly watched for, to protect mains.—*Martin E. Flentje.*

Information Relating to Analyses of Water Samples at the Laboratory of the Department of Health of the State of New Jersey. ANON. Public Hlth. News (N. J.) **22**: 5: 367 (Oct. '38). Water analyses to determine safety and potability are made (a) for an individual or corporation at a $15.00 charge (including bacterial, physical and some chemical tests); (b) for local health departments free of charge provided local officials cannot determine source of pollution without an analysis and "will prohibit use of water if it is found to be unsafe for drinking and household purposes." Bottled waters and non-alcoholic drinks are handled by special arrangement with state department.— *P. H. E. A.*

The Chemical Quality of Water for Human Consumption in Desert Regions. H. SCHOELLER. Chron. mines coloniales **6**: 552 ('38). Discusses the potability of water in relation to its content of sodium, calcium and magnesium chlorides and sulfates. Total and relative amounts of salts permissible in drinking water are limited by their physiological action. Higher salt content is tolerated in hot than temperate climate. Table given in which potable water is classified in 4 groups based on weight of dry residue per liter. Water giving more than 4.0 grams of dry residue per liter is unfit for continuous use. Drinking water of good quality may contain up to 115 mg. sodium, 5 mg. magnesium plus calcium, 177.5 mg. chlorine and 144 mg. sulfate per liter.— *W. P. R.*

TASTE AND ODOR CONTROL

Reservoir Treatment with Activated Carbon. E. A. SIGWORTH. Eng. Cont. Rec. **51**: 26: 16 (Jun. 29, '38); Can. Engr. **75**: 1: 6 (Jul. 5, '38). Addition of activated carbon to a reservoir first experimented with at Bath, Eng. Since then this method of application has been successfully employed at 15 plants in U. S. Carbon best introduced by means of boat equipped with lateral tubes from which carbon suspension can drip into reservoir on either side of boat. Continuous flow of water from reservoir into barrel maintained with hydrant pump, carbon being added by hand and suspension agitated to ensure thorough wetting of carbon. Addition of carbon the day following CuSO$_4$ treatment found beneficial, flocculation and settling being promoted. Settling periods allowed vary from 8 hrs. to nearly 1 week. If possible, reservoir should be taken out of service for at least 48 hrs. Alternative is to apply carbon in small doses at frequent intervals until desired amount has been introduced. Dosages employed have varied from 5 to 60 lbs. per mil. gal. Dosage required can be determined by following procedure with min. of equipment. Prepare carbon suspension by adding 1 level teaspoonful of dry activated carbon to 1 gal. of palatable water. Then add to gal. of water to be treated 8 level teaspoonfuls of the suspension, shake for 1 min. and allow to stand 20 min. Place 4″ square of absorbent cotton (from usual lb. roll) in small funnel, wet with sample, pack tightly and slowly pass sample through cotton, discarding first quart of filtrate. Examine filtrate for taste and odor, and repeat using larger dosage if necessary. Each level teaspoonful of suspension added is equivalent to 2.5 lbs. per mil. gal. At Milton, Penna., taste and odor developed due to oil gaining access to stream entering reservoir from break in oil line. Granular activated carbon, contained between screens placed in vertical position 6″ apart in flume which carried water from reservoir to distribution system, effected removal. Rate of flow through carbon was approx. 15 gal. per sq. ft. per min. Author considers application of powdered activated carbon to be preferable, as screens may require frequent replacement due to corrosion.—*R. E. Thompson.*

Superchlorination at Defiance, Ohio. FRANK S. TAYLOR. Ann. Rept. Ohio Conf. Water Purif. **18**: 105 ('38). Aeration, activated carbon, potassium permanganate and carbon dioxide have been found ineffective in preventing odor of cod fish which develops in Maumee R. water when lime is added for softening. Superchlorination and dechlorination with sulfur dioxide was experimented with over period of nearly 2 mos., using chlorine dosages as high as 16.5 p.p.m., but was not found of material benefit. Taste is believed to be due to amines. Only remedy found so far is to discontinue lime treatment. Even lime coating on mains and the rendering of water alkaline with soap results in the production of the fishy odor.—*R. E. Thompson.*

Elimination of Chlorphenol Tastes from Water. JOSEF WOLBER. Gas-u. Wasser **81**: 236 (Apr. 2, '38). Raw water from the Ruhr, containing phenols from wood carbonization plants, was formerly treated with filters of granular

activated carbon. Even periodical washings could not hinder occasional passing of chlorphenol tastes. Powdered activated carbon was therefore tried, mixing it with the water at the effluent of the primary filters and taking it out at the slow sand filters. This method gave full satisfaction, using 1.1 grams of pow. act. carbon per cu. m. water.—*Max Suter.*

Mysterious Phenol Taste Accounted For. ANON. Public Works **69**: 6: 16 (Jun. '38). An Illinois water plant operator has been bothered by complaints of chlorophenol tastes in the water reaching consumers, although chemical tests revealed no phenols in raw, settled or filtered water, and applying chlorine to the raw water produced no "medicine taste". After thorough investigation the mystery has been solved. Chlorine is applied to the filtered water as it passes to the clear well. This well is covered with a tar roofing paper and, due to temperature differences of the air outside and inside the clear well, condensation occurred and a "tar distillate" entered the clear well and chlorination only was needed to produce the disagreeable tastes.—*P. H. E. A.*

Flavor in Food. G. R. MAYBEE. Can. Chem. and Process Industries **23**: 115 (Mar. '39). Amount of material required to register sensation at olfactory cells is incredibly small. Strong smelling substances, such as trichlorphenol, can be perceived in one normal inspiration of breath containing only 0.000,000-000,01 gram: molecules of these substances are so small, however, that this quantity would contain 30,000,000,000. This appears to be min. that will cause sensation of odor. Emil Fischer, in 1887, showed that 1 vol. of chlorophenol in 1000 million vols. of air is at once detected. Observers have recently concluded that smelling, like hearing or seeing, is caused by electronic vibrations, as opposed to corpuscular or particle theory of odor perception, i.e., that odors are caused by particles which must be soluble in secretion of lining membrane. All workers agree that flavor involves simultaneous tasting and smelling, former being effected in mouth and latter in nose from vapors that come up from mouth by way of back of throat. Only 4 fundamental or "pure" taste sensations are recognized by physiologists, namely: sweet, sour, bitter and salt. Most of subtler discriminations usually attributed to palate are in reality performed by olfactory membranes. Tasting is a "milligram" sense, whereas smelling often involves millionths of a gram or less. Very disagreeable tastes are usually due to unpleasant odor sensations. On other hand, some volatile substances which enter mouth through nostrils and stimulate taste-buds are interpreted as odors. Some tastes, and also odors, neutralize one another without chem. reaction between substances causing them. Sodium chloride has threshold value of about 0.03 moles per liter, salty taste being still perceptible in 0.18% soln. Odors cannot be classified as simply as tastes. One observer concluded that 2000–4000 different odors can be distinguished from one another by av. individual. Good operator can detect odor-strength differences of perhaps 15–20%. Odors of weak solns. are most conveniently measured for intensity with nose extended by means of one of several types of tubes now in use, e.g., Fair Dilution Osmoscope, which dilutes air under test by 2:1 ratios with pure air. These 2:1 steps are plainly detect-

able by relatively untrained workers. In taste comparisons, using half-teaspoon amounts, most people can readily distinguish strength differences of about 10%. Persons of better than av. discrimination may make only 1 or 2 errors in 10 comparisons with 6% strength difference. Tasting ability varies considerably: large percentages of people are taste-blind to certain compounds. This wide disparity between individuals is accompanied by ignorance of their disability in most people who cannot discriminate, which further obscures the issue. It is essential, therefore, to have some means of testing palates of people considered as candidates for tasting-panel. Factors to be considered in tasting include: health, clean palate, successiveness of sensation, comparisons of sensations in memory, elimination of imagination and suggestion, elimination of all distractions, fatigue, age and temp. of sample, and listing of samples under key nos. so that tester knows nothing of their history. —R. E. Thompson.

Mechanics of Adsorption By Means of Activated Carbons. M. M. BRAIDECH. Ann. Rept. Ohio Conf. Water Purif. **17**: 23 ('37). Activated carbons, their sources and properties, nature of adsorption, measurement of adsorption capacity and evaluation of activated carbons are discussed. Adsorption is reversible and is intimately associated with surfaces. Powdered activated carbons as used in water treatment are reported to contain from 10 to upwards of 100 billion particles per gram and it has been estimated that a cu. in. has external and internal surface of over 20,000 sq. yds. Mechanism of adsorption by activated carbon is subject to considerable conjecture and debate: most strongly maintained opinion is that surface affinity is predominantly physical in nature and due principally to residual valencies of carbon atoms located at exposed surface. Adhesion-tension is said to be relatively powerful and, though physical in effect, resembles a "fixation" analogous to loose chemical union. This initial physical fixation, in some cases, may lead to formation of surface compound, i.e., chemisorption, which is irreversible. Adsorption is relatively greater and more complete in very dilute than in more concentrated solutions. Substances which lower surface tension of water most are adsorbed to greatest extent. Many taste and odor bodies are in this class. In experience, it has been found that time required to reach maximum adsorption equilibrium is usually 10–30 min., if thorough mixing is provided. Adsorption declines with rise in temp. and is largely dependent upon difference in electrical potential and pH. Adsorption is accompanied by evolution of heat energy, called heat of adsorption and sometimes referred to as heat of wetting, which parallels adsorption power of carbon. In discussing measurement of adsorptive capacity, partition law governing distribution of solute between two immiscible liquids is used as illustration and values corresponding to conditions in a carbon-water system are substituted to obtain Freundlich Adsorption Equation. Baylis phenol adsorption test is of definite value but is still an arbitrary one and should be supplemented by more direct threshold odor test. *In discussion,* R. W. ROWLEY suggested that two-step treatment, removing first dosage before second is applied, might be cheaper than single-stage treatment under severe conditions.—R. E. Thompson.

The Sorption of Chlorine by Activated Charcoal. L. H. REYERSON AND A. W. WISHART. J. Phys. Chem. **42**: 679 ('38). Sorption isotherms for chlorine on activated charcoal were obtained at 35.5, 51, 73.5 and 91.5°C. Isotherms are in agreement with Langmuir equation. Adsorption of chlorine is approx. same as that of bromine but about 10 times that of iodine. Min. surface area for the charcoal is about 4.3×10^6 sq. cm. per gram as judged by isotherms for chlorine.—*C. A.*

Evaluation of Activated Carbon for Water Purification. W. A. WELCH. Eng. Cont. Rec. **52**: 1: 14 (Jan. 4, '39). While the phenol adsorption test is best chemical method of determining inherent activity of activated carbon and serves as measure of extent to which activation has been carried insofar as ability to adsorb phenol is concerned, threshold odor test has advantage of making possible evaluation of carbons on water to be treated. There is no definite relationship between phenol value of a carbon and its ability to remove tastes and odors, due not only to selective action of carbons but also to factors which affect their dispersion, e.g., colloidal characteristics of carbon, and pH, turbidity and mineral content of water. There is likewise no definite relationship between amount of odor present and dosage of carbon required to effect removal, latter varying with type of odor present. Threshold value permissible in treated water also varies with nature of taste and odor present. —*R. E. Thompson.*

Critical Studies in the Preparation of Activated Carbon Specifications. L. A. MARSHALL AND M. M. BRAIDECH. Ann. Rept. Ohio Conf. Water Purif. **18**: 31 ('38). In Cleveland, continuous ammonia treatment prevents chlorophenol tastes and odors and practically eliminates chlorinous tastes, making possible use of higher chlorine residuals; otherwise, ammonia treatment is of limited effectiveness. Carbon treatment is employed as emergency method only. It is not always necessary to reduce threshold odor value to as low as 2 or even to 5. Temp. and character of taste and odor may be quite as important as threshold odor value. Cost of carbon treatment to reduce value to 2 may be prohibitive. Relatively high dosages to eliminate intensive tastes and odors which occur at infrequent intervals, however, are justified. Specifications under which carbon is purchased are given and basis on which they were formulated is discussed in detail. Carbon must have moisture content not exceeding 8% and phenol value (carbon, in p.p.m., dry basis, required to reduce 100 parts per billion of phenol to 10 parts per billion) not exceeding 30 (±10%). Carbon samples submitted are compared on basis of amount required to reduce threshold odor value of sample of Lake Erie water having initial value of not less than 15 (odor is increased, if necessary, by adding odor concentrates prepared by distillation) 50 and 90% in 1 hr. at 20-25°C. when stirred at 100-300 r.p.m. Contract is awarded on sample indicating lowest cost per mil. gal. of water treated. Payment is made on dry wt. basis. If av. amount of delivered carbon required to effect reductions of 50 and 90% is more than 5% greater than that of bid sample, price paid is in inverse proportion to amount required.—*R. E. Thompson.*

Powdered Activated Carbon Storage. E. B. Evans. Ann. Rept. Ohio Conf. Water Purif. **18:** 95 ('38). Heat from 75-w. bulb is sufficient to raise temp. of activated carbon to ignition point. Disturbance of heated material causes it to burn. If water is employed for quenching, fine spray should be used. Best method is to smother with wetted tarpaulin.—*R. E. Thompson.*

WATER SUPPLY—GENERAL

Water Supply Engineering. Progress Report of Committee of Sanitary Engineering Division. Proc. A. S. C. E. **65:** 429 (Mar. '39). The report covers matters relating to noteworthy water supply projects, catastrophes involving water supplies and progress in the art of water supplies as have come to the attention of the committee. *Metr. Water Dist. of Southern Calif.:* This mighty project for damming the Colorado R. involves construction of Parker Dam, an arch dam 320' above the foundation, and an aqueduct 250 mi. long, including 92 mi. of tunnel. Both dam and aqueduct have been completed. Plans are in preparation for a softening plant to reduce hardness from 250 p.p.m. and solids from 500 p.p.m. *Central Valley Project, Calif.:* This $170,000,000-project of the U. S. Bur. of Recl. is designed to bring waters of the Sacramento R. to the Delta and Suisun Bay region and to parts of the San Joaquin Valley. Shasta Dam is under construction and the Contra Costa Canal has been completed. Dam will be 560' high and will impound 4.5 mil. acre-ft. *Metr. Water Dist., Mass.:* This project will take water from the Swift and Ware Rivers for Boston. Principal structure is Quabbin Dam, a hydraulic-fill dam capable of storing 415 bil. gal. A pressure aqueduct, 23 mi. long, of which 18 mi. is immediate construction, is included in the project. *Supply for Metr. N. J.:* Water is to be taken from the Delaware R. in pipe on the abandoned bed of the Delaware and Raritan Canal and thence pumped to a reservoir to supply draft up to 250 m.g.d. *Delaware R. Supply for N. Y. City:* Construction of this project to supply 440 m.g.d. from the Delaware R. and 100 m.g.d. from Rondout Creek is proceeding rapidly. The Delaware system involves two reservoirs—Neversink and Rondout, 6 mi. of tunnel and an 85-mi. aqueduct, all to cost $210,000,000. The 85-mi. aqueduct will be a continuous, deep, pressure-tunnel, lined with concrete, 13.5' to 19.5' dia. More than 2 mi. of tunnel completed by end of '38. The contract times for completion would permit water to be supplied sometime in '41. *South Side Filter Plant for Chicago, Ill.:* Breakwaters and embankments for the coffer dam have been started at the site in Lake Michigan just south of 79th. St., where av. depth is 14'. Water will be taken from an existing intake tunnel, treated in a gravity plant and distributed to 3 pump stations. There will be 80 filter units, each with a capac. of 5 m.g.d., operating at rate of 2.5 gal. per sq. ft. per min. Plant will cost $17,000,000 and will supply 1,700,000 consumers. *Bartlett Dam, Highest Multiple Arch Dam:* This dam, on the Verde R., is 54 mi. north of Phoenix, Ariz. and is to be completed in May '39. It is 287' high and impounds 201,500 acre-ft. *Hartford, Conn., Metr. Supply:* Saville Dam, largest in Conn., is nearing completion. It is a rolled-earth structure with concrete core, 137' high, with spillway 200' long. It will supply

54 m.g.d. Cost will be $2,850,000. *Water Supply for Westchester County, N. Y.:* Two plans for a consolidated supply have been reported upon, one being for a supply from Conocus Creek, near Peekskill, at cost of $22,500,000; the other from N. Y. City aqueducts at a cost of $9,900,000, including filters. *Grand Rapids, Mich.:* A new supply to be taken from Lake Michigan will supplement the present supply from Grand. R. It will include an intake and pipe 8,000' long, a pump station, 30 mi. of pipe not less than 42", and covered reservoirs with total capac. of 40 mil. gal. *Additional Supply for Salt Lake City:* U. S. Reclamation Service will construct for joint use of Salt Lake City and Provo River Water Users Ass'n. a 50-bil. gal. reservoir at Deer Creek, and a 66" concrete aqueduct 40 mi. long to Salt Lake City. *Muskingum Dams in Ohio:* Fourteen flood protection dams to protect 675,000 persons are included in the project. The main reservoirs, which are on tributaries of Muskingum R., have total storage of 1,560,000 acre-ft. and will reduce the flood crest at Zanesville by 15'. *Floods in Southern Calif., Mar. '38:* Death loss due to the floods of Mar. '38 was approx. 200, and property loss about $50,000,000. Rain varied from 5" to 13", damaging mainly bridges, highways, and railways and some water mains. *Flood Damage on Eastern Slope of Rocky Mts.:* A 3-day rainstorm of high intensity in Sept. '38 caused $250,000 damage in an area from Colorado Springs to the Wyoming line. Recently constructed Sullavan Dam successfully passed the test. *New England Hurricane and Floods of Sept. 21, '38:* Damage by this record-breaking storm was increased by simultaneous river floods following a 9-day precipitation of 16". The 121-mile wind, aided by unusually low barometric pressures piled up the waters on the south shore of Long Island and the north shore of the Sound causing millions of dollars of property damage and great loss of life. Previous record storms occurred in 1635 and in 1815 but neither was so violent as this one. In Rhode Island the damage to water supplies included power failures, leaks in distr. mains, destruction and pollution of reservoirs, pollution by salt water, flooding of purification plants, decrease in filter runs, increase in chlorine demand, and breaking of hydrants. Damage to water works in Mass. estimated at $500,000. In eastern New York polluted water entered mains and chlorination was interrupted by power failures. In Conn. damage not so severe but power failures interfered with operation of pump stations, filter plants and chlorinating apparatus. Damage to trees was great in New Hampshire. *Frequency of Large Floods:* The grouping of 3 major floods in an 11-yr. period emphasizes the danger of misunderstanding the meaning of a 100-yr. flood period. *Slide at Fort Peck Dam:* On Sept. 21, '38 about 8-mil. cu. yd. of earth fill slid into the stream, burying 8 men. Failure of foundation shale was suggested cause. *State vs. Federal Jurisdiction over Watersheds in New England:* Controversies between the states and the Federal Government have resulted in the matter being brought on to the floor of Congress. *Tendencies in Financing Water Works Improvements:* In the Middle West there has been a tendency toward revenue bond financing of new construction. Low interest rate on this type of bond has resulted in transfer of many privately-owned water works to municipal control. There have been some instances of combined water works and sewer bonds. *Effect of W.P.A. on Construction:* Small contractors are increasingly reluctant to

figure on small distribution mains. A minor influence has also been exerted on water works buildings, designs being such as to give max. proportion of the cost to labor. *Trends in Construction of Earth Dams:* Methods of earth dam construction are influenced by the science of soil mechanics. New type of equipment has reduced unit costs. Experience is pointing to need for caution in applying laboratory results in design. Principles in the construction of rolled-fill and hydraulic-fill dams are presented. *Improved Portland Cement:* If the Portland cement now being produced lives up to its promises more durable hydraulic structures can be constructed. *Centrifugal Pump Developments:* Although there have been no outstanding developments certain trends have been accentuated. In deep-well turbine pumps water lubrication is increasingly used. Combination of split pumping units, involving a steam turbine, a pump, and an electric generator to drive low lift units are becoming more common. There has been a slight increase in the efficiency of ordinary types of centrifugal pumps. Steam-turbine driven pumps are increasingly used. *Progress in Design and Construction of Pipe Lines:* Increasing use of rubber rings in place of jute-filled lead gaskets for joints of reinf. concrete pipe. Welded pipe continues to be the almost invariable type of steel pipe in use. Cement-asbestos pipe with round rubber gaskets is used in considerable quantities. Cast-iron pipe is improved in quality, the bulk of sizes up to about 20″ being made centrifugally. Cement joints for c. i. pipe generally used on Pacific coast and sporadically elsewhere. By clinching steel bands around c. i. pipes in railroad cars in transit breakage has been reduced. Welded branches now available on c. i. pipe. Steel non-pull-out dogs available to prevent end pull-out of mechanical rubber-gasket joints. Design of c. i. fittings may be improved as result of tests on $\frac{1}{4}$ scale models and hard-rubber models. Popularity of cement linings has not yet taken hold despite low coefficients of the older types of linings. Spun bituminous enamel lining becoming standard for steel pipe and is used for some c. i. pipe. A high alumina cement lining has been used with satisfaction, as has spun cement lining for steel pipes. There is need for active study of the effect of time on various pipe coatings. Tuberculation is not prevented by treating the water to put it in chemical balance. Tar enamel, with or without asbestos wrapping, generally used for exterior protection. Water hammer is better understood and is provided for in more important pipe lines. *Progress in Knowledge of Utilization of Ground Water:* Recession of ground water and encroachment of salt water is being studied at many points. In many places water works have been mining ground water and not allowing it to be replenished. *Progress in Water Treatment:* Great increase in number of filter plants; improvements in sedimentation have resulted from principles introduced by Spaulding at Springfield, Ill.; separate filters with granulated activated carbon have been used; more attention being given to efficiency of sterilization; lime being recovered at softening plants for re-use. *Misc. New Designs and Ideas in Water Supply:* Insulated water meter connection to avoid galvanic action; construction of a groined arch roof for a large reservoir; construction of a 3-story, reinforced concrete reservoir in France; increase in number of elevated tanks $\frac{1}{2}$ to 2 mil. gal. capac., although production of tanks below 100,000 gal. has diminished.—*H. E. Babbitt.*

Urgent Need for Colorado River Water. F. E. WEYMOUTH. Eng. News-Rec. **121**: 639 (Nov. 24, '38). Interesting account of history of struggle for water in South Coastal Basin of Calif., which is inherently a desert, and of events leading up to construction of huge Colorado River project for 13 cities comprising Metropolitan Water District of Southern Calif. Median precipitation during 157-yr. period has not exceeded 13.5″. Repetition of drought of '04 could not be endured without aid from outside sources. Only possible source was Colorado R. The 1500-sec.-ft. diversion provided for will come reasonably near fulfilling ultimate needs of metropolitan area.—*R. E. Thompson.*

Ex occidente lux? (Light from the West?). PIERRE DESCROIX. L'Eau (Fr.) **32**: 25 (Mar. '39). Recent Los Angeles and New York City water projects are reviewed and praised for excellence of both planning and execution.—*Selma Gottlieb.*

Erie, Penna., 1938 Report of the Bureau of Water. 65 pp. Very complete tables of operating and financial data given. Av. daily consumption was 22.8 mil. gal., or, on basis of estimated pop. of 121,000, 188 gal. per capita. Cost of collecting, purifying and pumping water (including depreciation) was $33.805 per mil. gal. Av. dosages of chemicals and wash water used at Chestnut St. and West filter plants, respectively, were: alum, 0.218 and 0.24 g.p.g., chlorine, 1.54 and 1.65 lb. per mil. gal., activated carbon (intermittent application), 2.76 and 2.76 lb. per mil. gal., wash water, 2.51 and 1.46% of water filtered. Monthly data given concerning turbidity, alkalinity, color, temp., and no. of bacteria and coliform organisms in raw and filtered water. All of the 918 samples of filtered water examined for coliform bacteria in 10 and 1 cc. were negative. No. of gal. of water pumped per lb. of coal consumed averaged 382.28. Income exceeded expenditures by $44,783.41 and water to value of $62,627.64 was furnished for municipal purposes without charge. Reduction of 10% in water charges to domestic and all other flat rate consumers was made effective Jul. 1. Description of works and schedule of water rates is included.—*R. E. Thompson.*

Maryland State Dept. Health, Bur. San. Eng., Annual Report, '38. ABEL WOLMAN AND GEORGE L. HALL. 33 pp. Extensive activities in fields of water supply, sewage purification, industrial waste disposal, stream pollution abatement, oyster surveys, mine sealing, etc., are reviewed and outstanding developments in state in regard to these particulars are outlined. Total value of work represented by all plans submitted for review during yr. amounted to approx. $3,300,000. During past 2½ yrs., 22 mines were sealed, reducing acid discharged therefrom from 1300 to 570 tons per yr. In addition, surface sealing (crack filling, paving of streambeds and building of masonry retaining walls to prevent overflowing on to adjacent ground during high water) has been carried out in 4 stream basins. Total cost approx. $80,000. There are 140 public water supplies in state, 69 of which receive treatment in some form. Of latter, 45 are given supervisory attention with object of "refining" quality of water delivered and keeping operator informed of new

developments. In Nov., outbreak of diarrhea occurred at Bel Air, cases numbering approx. 663. Sources of supply found to be satisfactory in quality, but tap samples were contaminated. Cause not yet determined. Chlorination adopted. Details are given of compact which will be submitted legislatures of states concerned in pollution of Potomac R., with object of forming Potomac Valley Conservancy District. Death rate from typhoid and paratyphoid was 1.9 and 2.7 per 100,000, inclusive and exclusive of Baltimore, in which rate was 1.0.—*R. E. Thompson.*

Snyder, Okla., Goes to the Hills for a Surface Water Supply. F. M. HIERONYMUS. Eng. News-Rec. **122:** 224 (Feb. 16, '39). Brief description of recently completed water supply system of town (pop. 1200) located in region which is often without rainfall for many months and where importation of water in tank cars is not unusual. Underground supplies very hard and uncertain: 3 wells drilled in '36 failed in '37. New system, built at cost of $125,000, consists of earth dam storing runoff from headwaters of Otter Creek in Wichita mountains, 0.36-m.g.d. filter plant below dam, and electrically-driven pumps to lift filtered water to 50,000-gal. concrete reservoir, from which water flows through 6 mi. of 8" welded steel pipe to storage reservoir in town. From latter, water is pumped into existing 80,000-gal. steel pressure tank which feeds distr. system. Alum, lime and chlorine used. Water is soft and ample in volume.—*R. E. Thompson.*

A Survey of Current Water Works Practice (in Ontario). G. A. H. BURN. Eng. Cont. Rec. **52:** 15: 45 (Apr. 12, '39). General discussion, relating particularly to Ontario. In '37, there were 284 public systems, with 243 separate sources of supply, serving 60% of total population. About 30% of supplies are derived from underground sources, over 80% of such supplies being in communities with populations of 5,000 or less. Chlorination is part of treatment provided in 130 supplies and filtration in 61. Of latter, 32 plants are of pressure type and 23 mechanical gravity. Alum is most commonly used coagulant. There is definite trend toward employment of coarser filter sand and reduced depth. In plants of recent design, depth of sand greater than 24" is uncommon. Effective sizes of from 0.45 to 0.6 mm. are now general. Softening employed at 3 plants in Ontario and taste and odor control at 18. Of latter, 10 use activated carbon and 3 chloramine. In recent yrs., more attention has been given to architectural features of waterworks buildings. Additional cost of building which is attractive in appearance is slight compared with total cost. Careful attention should be paid to exterior surroundings and similar care should be devoted to interior. Absolute cleanliness highly desirable. Other subjects dealt with include chlorination, taste and odor control, contamination in distr. system, cross-connections and plumbing hazards, importance of records, certification of personnel, and sterilization of new mains. For latter, min. chlorine dosage usually recommended is 50 p.p.m., with contact period of at least 3 hrs.—*R. E. Thompson.*

Directory of Important Water Supply Systems of Canada. ANON. Eng. Cont. Rec. **52:** 15: 60 (Apr. 12, '39). Authoritative and up-to-date data,

alphabetically arranged by provinces, concerning water supplies of leading cities and towns in Canada. Data given include: population, source of supply, treatment employed, distr. system details, consumption, etc.— *R. E. Thompson. See also* Can. Engr., Annual Directory (Jul. 11, '39).

Directory of Waterworks Officials of Canada. ANON. Eng. Cont. Rec. **52**: 15: 82 (Apr. 12, '39). Names of engineers, superintendents and commissioners of municipal water supplies in Canada, latter being listed alphabetically according to provinces.—*R. E. Thompson. See also* Can. Engr., Annual Directory (Jul. 11, '39).

Water Supply in Relation to Public Health. W. J. E. BINNIE. Wtr. & Wtr. Eng. **40**: 246 ('38). About 95% of the population of England and Wales is at present provided with piped water supply. Approx. two-thirds of this supply comes from surface waters, either storage reservoirs, rivers or streams. The remainder is obtained from underground sources. General discussion of sources of water supply and methods of treatment.—*Condensed from B. H.*

Emergency Water Supply for London (England). ANON. Wtr. and Wtr. Eng. (Br.) **41**: 203 (Apr. '39). Water supplies for fire fighting in time of war are a major consideration in London today. Schemes have been formulated for pumping water from the Thames by means of fire boats, together with methods for relaying water by means of pumps and hose for distances as great as 4 mi. A scheme has been drawn up for the laying of 1,800 canvas reservoirs throughout the central London area, with capacities ranging from 1,400 to 12,000 gal. each.—*H. E. Babbitt.*

International Water Exhibition, Liège 1939. *Editorial.* Deut. Wasserwirtschaft **34**: 187 (Apr. '39). Held in connection with celebrations attending the opening of the Albert (Liège to Antwerp) Canal. Covers fully every aspect of water and of its rôle in relation to man. Its scope includes:—instructional and professional courses; water in science and in engineering (water in nature, rivers, canals, estuaries, seas; inland, marine, and fishing harbors; water engineering in town and country; water purification; water turbines, etc. and power stations; water-power and electricity; refrigeration; water in industry); shipping; fishing; science and technical applications of water in tropical countries and colonies; water and business in general. Germany's building covers 6400 sq. meters; it was designed by Prof. E. Fahrenkamp of Berlin-Düsseldorf; reproductions are given of its plan and a photo of a small scale model of it by the designer.—*Frank Hannan.*

What is the Consumption of Water in France? PIERRE DESCROIX. L'Eau (Fr.) **32**: 13 (Feb. '39). Of 21,000,000 pop. in French cities over 5,000 inhabitants, 20,000,000 are served by public water supplies. Only 5,000,000 of rural population are served. Using estimates of 127 liters daily per capita consumption in urban districts and 30 liters in rural districts, pop. supplied would use 995,000,000 cu. m. of water per yr., but greater consumption in Paris increases this figure by 89,000,000 cu. m. per yr. Annually 255,000,000 cu. m.

of non-potable water are used in public service bringing total volume of water distributed in France per year to about 1,345,000,000 cu. m. Survey by Professional Syndicate of Water Distributors shows that privately owned systems supply to 7,000,000 inhabitants 280,000,000 cu. m. of water per yr., distributed to 810,000 subscribers through 17,000,000 meters of pipe.—*Selma Gottlieb.*

Water Supplies of Germany. E. KIRCHNER. Rdsch. tech. Arb. **17**: 38: 3 ('37); Gas-u. Wasser. **81**: 441 ('38). About 4,000 central water supply organizations in Germany have recently united in the Reichsarbeitsgemeinschaft der Deutschen Wasserwirtschaft to which the Wirtschaftsgruppe Gasund Wasserversorgung and the Deutsche Verein von Gas-und Wasserfachmannern belong. Hydrological, geological, hygienic, chemical and economic problems concerned with municipal and rural water supplies will be dealt with in the forthcoming State Water Law and water supply regulations. The amount of water required for central supplies in Germany is estimated at 2.7 thousand mil. cu. m. a year.—*W. P. R.*

Statistics on Water Consumption. EDWARD WENGER. Gas-u. Wasser. **82**: 237 (Apr. 8, '39). Data on the consumption of water in German cities are given. Cities divided into groups according to population and for each group is shown the highest, average and lowest value within the group of max., av., and min. consumption. Av. consumption varies between 30 and 40 gal. per capita per day, with a peak up to 53. Min. consumption can be as low as 15 gal. per capita per day. As a general rule an increase per capita per day is found with an increase in population, although a secondary peak was found in the group of cities with a population of 100,000-200,000. The highest consumption is from 2 to 2.5 times the lowest, the difference being greater in smaller cities. Yearly variations are very uniform in all groups. '29 was a year of high consumption, whereas '33 was low, from 30 to 45% below '29.—*Max Suter.*

WATER RATES AND FINANCING

An Experiment in Public Relations. G. W. KNIGHT. W. W. and Sew. **85**: 636 (Jun. '38). The Natrona (Pa.) Water Co., during the hot, dry summer of '36, offered to sell water for sprinkling etc., at ⅓ the usual rate. Low rate was charged for excess of water taken by consumer over previous summer quarter. Water consumption increased 16%, revenue –2.6%, and only 17.6% of customers participated in offer. Accounting and billing was complicated, and customer relations were not improved. Plan was not repeated in '37.— *H. E. Hudson, Jr.*

How Should a Waterworks Charge Outside Municipalities. W. L. McFAUL. Eng. Cont. Rec. **52**: 24: 16 (Jun. 14, '38). Generally speaking, urban municipality must be prepared to supply suburban communities. Requirement for adequate supply provides sufficient excess to take care of marginal regions. Rates to outside municipalities will usually be considerably higher than in community owning the utility: in Hamilton, Ont., rates are 50% higher, owing

to fact that value of plant is much greater than indebtedness. Where there is limited waterworks organization in outside municipality or there is probability that outside system may be taken over at some future date, it is desirable that design and construction of suburban system be supervised by urban community. Fixed charge, in addition to consumption charge, should be made for fire protection in marginal territory. Arrangements for standby connections between adjoining municipalities for mutual protection or for protection of suburban community are also discussed briefly.—*R. E. Thompson*

Minimum Charges for Billing Periods. Anon. W. W. Inf. Exch., Canadian Sect. A. W. W. A. **3**: B: 2: 6 (Mar. '39). Tabulation of min. domestic water charges in 112 Canadian municipalities is given. Data include billing period, min. charge for period and yr. under metered and flat rate schedules, and amount of water allowed for min. charge under metered rated schedules. Yearly min. varies from $2.00 to $27.00 under metered rate schedules and from $2.00 to $36.00 under flat rate schedules.—*R. E. Thompson.*

Dollars for the Utilities. The Extent and Nature of the 1938 Financing and Its Significance. Merwin H. Waterman. Pub. Util. Fort **23**: 396 (Mar. 30, '39). The total amount of public utility financing done in '38 approximated that of '35, but was far short of the "recovery level" of '36, exceeding slightly the financing of '37; total public and private utility sales approx. $1,230,000,000. Tabulation of total public offerings only shows approx. $2,400,000,000 in '30 decreasing to approx. $92,000,000 in '33 increasing then to over $900,000,000 in '38, notable, however, is the fact that in '30, 80% of the offerings were for expansion and slightly over 10% for refunding, there has been a steady transition until now the percentages are reversed. 10% for expansion and 85% for refunding. Of about $95,000,000 expansion financing, by public offering of securities, slightly over $90,000,000 by bond issues, remainder equity financing in form of preferred stocks. Investment bankers participated in preferred issues, none made a firm commitment where stock sale was to provide new money, thus bankers showed lack of confidence in utility expansion funds being absorbed by the market. Under present conditions, expansion money must be raised by bonding, issuer must pass a market test and have SEC approval. Equity financing restricted by the market, debt financing only by utilities trading on existing equity; reinvesting earnings only means of expansion except by superstrong units. Restoration of investor confidence necessary for new capital, utilities must be active competitors for the equity investor's dollar. Necessary to influence government's attitude toward utilities and management's towards running its own business. Government's impartiality could be brought about by making other industries' futures as uncertain as utilities, or lightening utility inquisition and limiting government competition and politics. Refunding money dropped to average of 3.63% in '38, making possible extension of refinancing programs. Safe prediction, little more refunding profitable at current or higher money rates. Securities Act registration requirements have vitally affected "orthodox methods" of security distribution. Fall River Electric Co. $2,000,000 issue in May, '38, 3⅛% bonds, was bid for at

prices to give costs ranging from 3.018% to 3.123%; was then offered to public with 1.9 points mark-up. This spread is precise average of all issues during the year. Banking services largely entirely dispensed with in utility and industrial fields, $308,000,000 utility bonds sold '38 by direct contact between issuers and investors; very existence of bankers is at stake. Private offerings limited to highest of high-grade issues. Holding Company Act now requires many of same expenses and delays as registration under Securities Act. With SEC approval, preferred stocks and debenture bonds of The North American Co. "went out of the window" in Feb. '39, demonstrating holding company securities could be sold if—; '39 developments will bring forth the ifs.—*Samuel A. Evans.*

Rating and Valuation of Water Works. ANON. Surveyor (Br.) **95:** 467 (Mar. 31, '39). *Inst. of Water Engineers.* The present system of rating and valuation has grown up as a result of long series of court decisions. The effect has been to produce an unfair and oppressive system by which a works with a large debt has a large valuation and one with a small debt a small valuation, being out of line with the true capitalization.—*H. E. Babbitt.*

WATER FOR AIR-CONDITIONING

Use of Cooling Water in Air-Conditioning. WALTON H. SEARS. J. N. E. W. W. A. **52:** 452 (Dec. '38). Air-conditioning is of interest to the water works industry because most installations require water; many require large quantities of it. True air-conditioning should control temp., control humidity, supply ventilation, provide controlled circulation of properly·tempered air and cleanse the air. For summer air-conditioning minimum requirements are cooling of the air, dehumidification and circulation of the air; for winter, air must be heated, humidified and circulated. Water required for winter air-conditioning negligible. Summer air-conditioning requires large quantities, and coming in period of water works max. demand causes concern to operators. Amount of water req'd. varies greatly with individual installations. Average amount of heat that must be removed per hr. per person, expressed in B.t.u., for residence—4000, office—4700, restaurant—2000, theater—1000. Max. demand of water (in New Eng.) for same locations respectively is: 40, 47, 20, and 10 gal. per hr. Not necessary to waste all water used, 90-95% may be cooled by means of cooling towers and similar devices and re-used; 60% of country's air-conditioning installations have water-conserving devices. Av. water requirements in gallons per person equals 300 gal. per day max. if no evaporative condensers or cooling towers used, 130 gal. per day per person according to '35 practice with 60% of installations conserving water, and 15 gal. per day per person if installations were 100% equipped with evaporative condensing and cooling towers. Hard to make estimate of water requirement for specific community, often electric utility has record of total hp. devoted to air-conditioning. This figure, with fact that roughly 1 hp. req'd. for each 5 persons, allows rough approximation. To water systems with ample supply and adequate distribution facilities, increased water use due to air-conditioning brings added revenue without additional investment; those systems with limited supply or limited dis-

tribution system, the air-conditioning demand of about 3 mo. duration may be real manace. Author believes fair and reasonable water-conserving devices should be mandatory where conditions require it.—*Martin E. Flentje.*

Conservation of Water by Using Cooling Towers and Evaporative Condensers. SAMUEL I. ROTTMAYER. "Second Conference on Air-Conditioning", Univ. of Ill., Mar. '39. p. 127. Water-cooling towers are heat exchangers in which an intimate contact of condenser water with atmospheric air is achieved, promoting release of heat from water to the air. Evaporative condensers are heat exchangers in which a transfer of heat occurs directly to the air from the liquid refrigerant containers. Water-cooling towers used in connection with air-conditioning refrigeration may be classified as: (a) atmospheric type, which depends on wind motion for operation, (b) mechanical draft type, which employs induced or forced draft fans for producing air movements through the tower. The humidifying air washer is a modification of an induced draft cooling tower. The evaporative condenser is a combination of a refrigerating condenser and a mechanical draft cooling tower. The atmospheric tower is the most common type of tower used for general refrigerating purposes. It is constructed of wood or steel framing, supporting a filling consisting of a series of horizontal decks or splash bars equally spaced from top to bottom. The evaporative condenser combines an induced or forced draft cooling tower with a refrigeration condenser. An evaporative condenser secures a higher heat transfer rate from the refrigerant to the air than is possible with any arrangement using water alone. The quantity of make-up water required by each type of air-contacting equipment is equal to that lost by wind or drift plus that evaporated. If city water at 76°F. is used for condensing purposes, with the warmed city water wasting to the sewer, the water consumption per ton of refrigeration will be: (1) 1.58 g.p.m. for mechanical compression refrigerating system, (2) 4.65 g.p.m. for steam-jet refrigerating system. The saving in water consumption if a cooling tower should be used would be: (1) 96.5% for the compression system, and (2) 96.9% for the steam-jet system. A value of 90 to 95% is generally taken as the water conservation effected by the use of cooling tower equipment.—*H. E. Babbitt.*

Air-Conditioning Water Supply and Disposal. W. D. GERBER. "Second Conference on Air-Conditioning", Univ. of Ill., Mar. '39. p. 118. Basis for this paper is the desire of many persons to obtain air-conditioning by use of cold water and to waste it after it has served that purpose. Surface water, while plentiful in Illinois, is too warm during the summer season, and in most cases could become available only through the municipal distribution system. Deep-rock well water generally has a higher initial temperature than is desired. Unless large quantities of water are required the cost of construction would be more than the project could afford. Limestone and sandstone water from wells not exceeding 400' deep is generally attractively cool and in areas where such water may be obtained is a desirable medium for use in air cooling plants. Construction of wells of this depth does not involve prohibitive cost. The likelihood of developing a satisfactory well

at the building site within limestone areas is more promising than for most
other aquifers. Sand and gravel beds in the drift will furnish a water of
desirable temperature, provided such beds are known to exist below the site.
Assuming that ample water is available, there arises the question of disposal.
Three methods suggest themselves: discharge into a nearby water course,
discharge into sewers or drains, and discharge into receiving or drainage
wells. Under the last condition the cool ground will become warmed by
the returned water and the efficiency of the conditioning unit will be lowered.
From experiences reported it appears that some study must be given to the
design of the absorption well. Reports further seem to indicate that such
wells require more attention and maintenance than do producing wells.—
H. E. Babbitt.

HYDRAULICS

A New Method of Presenting Data on Fluid Flow in Pipes. A. A. KALINSKE.
Civ. Eng. **9**: 313 (May '39). The presentation of fluid friction data for pipes
by plotting the friction factor, f, against Reynolds' number, R, has been ac-
cepted as the ideal method of correlating such data. Prandtl and von Kar-
man have shown by an analysis of the inner mechanism of turbulence, that
for hydraulically smooth pipes $\dfrac{1}{\sqrt{f}}$ should be a function of the quantity $R\sqrt{f}$
which we can call K. This term is quite useful as it can be calculated if the
pressure loss is known but not the velocity. To calculate the Reynolds
number the velocity must be known. For flow in extremely rough pipe,
experiments indicate that above a certain value of R, f is independent of R,
in other words, viscosity has no effect on the value of f, and that f is dependent
only on relative roughness, k/r, where k is the height of the roughness pro-
jections and r is the radius of the pipe. The problem now remaining is how
all experimental data for commercial pipe can be correlated for all values of
R so that the data for all sizes will follow one smooth curve, i.e., what can be
done in the region where both viscosity and pipe roughness affect the value of
f? This is the region in which most practical pipe computations fall. By
dimensional analysis and other considerations it can be shown that

$$\frac{1}{\sqrt{f}} = \phi \log_{10}\left(\frac{k}{r}R\sqrt{f}\right) + 2\log_{10}\left(\frac{r}{k}\right) + C \ldots\ldots\ldots\ldots(5)$$

in which ϕ means "a function of", and C is a constant. Values of ϕ and C
for different conditions are discussed.—*H. E. Babbitt.*

Direct Solution of Isothermal Flow in Long Pipes. C. F. BONILLA. Ind.
Eng. Chem. **31**: 618 (May '39). Applications of dimensional analysis to
study of fluid flow in pipes is reviewed briefly. Trial-and-error solution for
flow rate or pipe size is unnecessary if all dimensionless ratios available are
used, i.e., Reynolds number, friction factor, von Kármán number and size
factor. In each dimensionless ratio some one fluid flow variable is missing,
enabling immediate calcn. of ratio omitting the unknown. This value is
then plotted against any other and the unknown thus calcd. Several plots

are shown. One or two curves only can be made to cover all possible cases. Complete exposition of the several dimensionless ratios may help to clarify study of fluid flow considerably.—*Selma Gottlieb.*

Considerations of Flow in Large Pipes, Conduits, Tunnels, Bends, and Siphons. JAMES WILLIAMSON. J. Inst. C. E. No. 6: p. 451. (Apr. '39), *also* Surveyor (Br.) **95**: 287 (Feb. 17, '39). The following nomenclature is used: g, the acceleration of gravity in ft./sec^2; c, Manning's coefficient equal to $1.486/n$; d, the dia. of a circular conduit, ft.; k, the coefficient of absolute roughness, developed by J. Nikuradse in '33; n, Kutter's coefficient of roughness; n_m, the value of n for a model and n_a, the value of n for its prototype; R, the hydraulic radius, in ft.; S, the hydraulic gradient; and V, the av. velocity of flow, ft. per sec. The flow in straight pipes and conduits can then be formulated as $V = cR^{2/3}S^{1/2}$. The coefficient k is approx. proportional to the sixth power of n. In straight pipes the velocity is not uniform, being less at the sides and more at the center. The variation from uniformity increases with increase in the relative roughness. In pipes of different diameters, flowing with roughness effect fully developed, there will be approx. similarity of flow under comparable conditions when scalar relationship is maintained between absolute roughness and diameter, i.e.,

$$\frac{d_1}{n_1^6} = \frac{d_2}{n_2^6} \quad \text{or} \quad \frac{d_1}{k_1} = \frac{d_2}{k_2}.$$

The mean kinetic energy in straight pipes is more than $V^2/2g$, and when the flow is steady can be evaluated by arithmetical integration from the velocity curve taken across a diameter. In pipes of the same diameter the excess kinetic energy over $V^2/2g$ increases with increase in the coefficient of roughness. Increase in kinetic energy without increase in the quantity flowing is induced by other means than the roughness of the pipe, this increase is accompanied by further increase in friction. Such other means producing increase of kinetic energy are: (a) vortex motion imposed by flow around bends, and (b) jet-conditions produced at the outlet ends of sharp bends. Losses in bends follow similar laws to the losses in straight pipes, but are on a higher scale. They vary directly as V^2 and n^2 and inversely as $R^{1.333}$. Under variations of scale, velocity and roughness the number of diameters of actual straight pipe which represents the loss in a bend will remain constant. The formula $S = \dfrac{V^2 n^2}{2.2\ R^{1.333}}$ will be applicable for variations of V, n, and R in the case of losses in bends. The laws for bends in pipes apply also to bends in siphons. The flow in a siphon is equivalent to the flow through straight pipe of the same cross section but of greater length. The increased length for purposes of calculation can be obtained by adding the appropriate extra length for each bend and making suitable adjustments where changes of section produce changes of velocity. Where there is a constant quantity flowing but variation of cross section produces changes of velocity, the loss varies as $V^{2.67}$. The results of model tests on siphons can be correlated approx. to the results to be expected on full size prototypes, provided that proper

allowance is made for change in scale and change of roughness by means of the pipe-flow formula, and that account is taken of the limitations arising from atmospheric pressure. Size of passages in the model and the nature of the surface should be such that the minimum diameter of passage should not be less than 2″. To obtain the correlation, it is necessary that the values of n_m and n_a be known. A model tested under atmospheric pressure will give no indication as to whether or not high-vacuum conditions with adverse effect on the flow may occur in the full-size siphon. In order to give such indications the model must be tested under suitably lowered air pressure. A short description is given of a siphon installed at the Loch Doon Dam and on the Glenlee Tunnel of the Galloway Water Power Scheme in Scotland. The surge tank at the Glendale Power station is 24′ dia. and located at the end of the $3\frac{3}{4}$-mile pressure tunnel. The tank was designed from the modification of Thoma's formula in the form $T = \dfrac{0.074\, D^{1.67}}{nH^{0.5}}$ in which T is the dia. of the tank, D is the dia. of the aqueduct, and H is the min. working head on the turbines.—*H. E. Babbitt.*

Turbulent Flow in Pipes with Particular Reference to the Transition Region between the Smooth and Rough Pipe Laws. CYRIL FRANK COLEBROOK. J. Inst. C. E. (Br.) No. 4: p. 133 (Feb. '39). The discovery of Osborn Reynolds that the change from stream-line to turbulent flow depended on the value of $\dfrac{\rho v d}{\mu}$ led later workers to the corollary that the coefficient λ in the well-known pipe formula $h\, \dfrac{\lambda l v^2}{2gd}$ is a function of the parameter $\dfrac{\rho v d}{\mu}$, which has been called Reynolds Number. In the above expressions ρ is the density of the liquid, μ is its viscosity, v is its mean velocity, d is the diameter of the circular conduit, g is the acceleration due to gravity, and h is the head loss due to friction in a length of straight pipe l. If Reynolds number be designated by the symbol R then: flow in hydraulically smooth pipes can be expressed as

$$\frac{1}{\sqrt{\lambda}} = 2 \log \frac{R\sqrt{\lambda}}{2.51} \text{ and in rough pipes as } \frac{1}{\sqrt{\lambda}} = 2 \log 3.7 \frac{d}{k}$$

in which k is the wall particle size in rough pipes. The experimental results of Nikuradse show complete agreement with the above laws provided, for rough pipes, values of R' exceed 60, whilst for values less than 3 even rough pipes obey the smooth-pipe law as the excrescences then cease to contribute to the resistance. Between these values of R' there is a transition from one law to another. The term R', which may be called the "roughness Reynolds number", is expressed as $\dfrac{\rho v' k}{\mu}$ in which v' is the "shear-force" velocity and is equal to $\sqrt{\dfrac{\tau}{\rho}}$ in which τ is the shear stress at the wall in the case of smooth

pipes. For the transition zone the following general formula is obtained

$$\frac{1}{\sqrt{\lambda}} = -2 \log\left(\frac{k}{3.7d} + \frac{2.51}{R\sqrt{\lambda}}\right)$$

which is in exact agreement with the theory at extreme values of R' and gives results in the transition zone which approximate very closely to the experimental values. The transition curve merges asymptotically into the smooth- and rough-law curves. All formulas in the paper are non-dimensional and it is possible to use the results in any system of units. Since the transition curves are complex, five design curves based on these functions are included in the paper in order to facilitate calculations. Similar tables for gas, air, and other fluids may be compiled by means of the transition curve.—*H. E. Babbitt.*

Fluid Resistance in Pipes. M. P. O'BRIEN, R. G. FOLSOM AND FINN JONAS-SEN. Ind. Eng. Chem. **31**: 477 (Apr. '39). A pipe is "smooth" in the hydraulic sense if the resistance coefficient in turbulent flow is affected by the viscosity but not by small changes in the surface roughness. A pipe is "rough" if its friction coefficient is independent of the viscosity, i.e. if the coefficient is a constant on the Reynolds number diagram. Between rough and smooth in this dynamic sense lies almost the entire range of flow conditions that are of engineering importance. This paper considers the extent to which present concepts of the nature of fluid resistance permit the prediction of head loss in this transition zone. For rough pipes von Kármán gives the equation

$$\frac{1}{\sqrt{f}} = 2.07 \log_{10} \frac{r}{k} + 1.50 \text{ (I), and Nikuradse gives}$$

$$\frac{1}{\sqrt{f}} = 2.0 \log_{10} \frac{r}{k} + 1.74 \text{ (II)}$$

in which f is the friction coefficient in Weisbach's equation $h = f \dfrac{L}{D} \dfrac{u_m^2}{2g}$; r is radius of pipe, ft.; k is size of sand grain forming roughness, ft.; h is head loss in distance L, ft.; L is length of pipe, ft.; d is diameter of pipe, ft.; u_m is mean velocity of flow in pipe, ft./sec.; and g is gravity, ft./sec.^{2}. A table of equivalent values of k for common surfaces is given. In commercial pipes roughness is non-uniform. On basis of experimental data it is concluded that: The general resistance curve suggested by Nikuradse is not typical of commercial pipes in the transition region between smooth and rough pipes; the ratio k/B is not an adequate criterion of the limits of smooth and rough pipes, if k is the equivalent roughness computed from equation (II), and B is the thickness of the laminar sublayer which surrounds the central core of fully turbulent flow in a pipe. Although the theory of turbulent flow has been useful in explaining the nature of resistance and has produced useful results in a number of related fields, it has not provided the engineer with an improved method of computing the head loss in pipes.—*H. E. Babbitt.*

Nomogram for Pipe Flow. JARL KUUSINEN. Tek. Fören. i Finland Förh. **59**: 31 ('39). Nomogram has been constructed with scales for pipe diam., mass velocity, vol. velocity, temp., power requirements, linear velocity, pressure for air and steam, pressure and velocity heads, Reynolds nos., viscosity, density, kinematic viscosity and pressure drop. Special pads of blank nomograms in c.g.s. units for use in computation may be ordered from Abo University.—*C. A.*

Exponential Formula Graphs. HAROLD K. PALMER. Eng. News-Rec. **122**: 451 (Mar. 30, '39). Exponential formulas involving 3 variables of form $X = C Y^m Z^n$ can be represented by alignment chart or by group of straight lines drawn on logarithmic paper for given value of C. Construction of such a chart for Scobey formula for flow in riveted pipes is described.—*R. E. Thompson.*

Turbulence and Diffusion. HUGH L. DRYDEN. Ind. Eng. Chem. **31**: 416 (Apr. '39). Deals mainly with fundamental concepts and theory of turbulence in relation to diffusion. Practical applications are found where stream-line flow or turbulent flow is desired in a pipe. The point of change occurs when the product of the mean speed by the diameter of the pipe divided by the kinematic viscosity of the fluid is well above 2,000. A second practical application of the theory here propounded is to be found in an arrangement for promoting rapid mixing through the introduction of the diffusing fluid through high-speed jets into a slow-moving fluid or even into a counter-current. A third method of securing turbulence is to introduce obstacles into the flow. In any actual device all three of these methods of securing turbulent diffusion may be operative. Isotropic turbulence is a uniformly distributed eddying motion in which the components in different directions have the same average magnitude and in which there is no correlation between the components in different directions. The measurement of the intensity (root-mean-square) of turbulence of an air stream has been facilitated by use of the hot-wire anemometer, and it has been shown that isotropic turbulence has two statistical properties; intensity and scale. In the general case of nonisotropic turbulence the single measure of intensity of isotropic turbulence is replaced by six quantities and the single measure of scale by six; thus 12 quantities are required to specify the state of turbulence in the neighborhood of a single point.—*H. E. Babbitt.*

Eddy Diffusion. W. L. TOWLE AND T. K. SHERWOOD. Ind. Eng. Chem. **31**: 457 (Apr. '39). Eddy diffusion is the process by which mixing takes place in a fluid stream in turbulent motion. In engineering practice the common condition is that of transfer of material to or from a fluid moving in turbulent flow. Adjacent to the phase boundary is a thin layer moving in viscous or laminar flow, called the laminar layer. The velocity increases from zero at the phase boundary to a critical value at the other face of the laminar layer beyond which the flow is turbulent. For many cases of importance in gas flow it is evident that the eddy layer represents an appreciable fraction of the total resistance to diffusion, and that the effective film thickness may be considerably larger than the thickness of the laminar layer. The rate of evapora-

tion of liquids into a turbulent air stream in a wetted-wall column is proportional to the 0.44 power of the molecular diffusivity of the vapor in air. The Stefan equation indicates that the rate should vary as the first power of this quantity. The aim of the investigation was, therefore, to find if the eddy diffusion is proportional to the concentration gradient and is it dependent on the nature of the diffusing gas. The results show definitely that the rate of eddy diffusion is proportional to the concentration gradient, and the agreement of the hydrogen and carbon dioxide data shows that the molecular weight of the diffusing gas is not important.—*H. E. Babbitt.*

Effect of Screen Grid on the Turbulence of an Air Stream. W. L. Towle, T. K. Sherwood and L. A. Seder. Ind. Eng. Chem. **31**: 462 (Apr. '39). The technique developed for measuring eddy diffusivities serves as an aid to the determination of turbulence in fluid flow. Although it might seem that the presence of a grid should increase turbulence in such a way as to speed up eddy diffusion it was found in the tests that it was decreased. The rate of diffusion is reduced because the eddies are smaller, even though the individual eddies may be rotating more rapidly, with larger deviating velocities as a result. The results show that normal flow conditions are restored about 45 diameters downstream from the grid. It checks the general rule, familiar to engineers, that flow meters are best installed 50 diameters downstream from a bend or other disturbance in the line —*H. E. Babbitt.*

Laws of Turbulent Flow in Open Channels. Garbis H. Keulegan. J. Research. Nat. Bur. Standards **21**: 707 (Dec. '38). Theoretical investigations of the phenomena of turbulent flow by Prandtl and Kármán have prepared the way for rational interpretations of experimental results. In these investigations two distinct relationships of basic importance are expressed. First, in a unidirectional turbulent flow the apparent shear at any point depends on the square of the velocity gradient at that point and, second, the factor of proportionality in the relation of the apparent shear to the square of the velocity gradient is determinate once the similarity of turbulence is assumed. This paper is an attempt to apply these principles to the problem of turbulent flow in open channels, mainly for the purpose of developing formulas for resistance for mean flow in forms similar to those obtained for circular pipes. Kármán's law for velocity distribution in the neighborhood of a solid wall can be expressed mathematically as

$$\frac{u}{u_*} = \frac{1}{\kappa} ln \left(\frac{y}{y_0} \right)$$

in which

u = velocity at a point
u_* = shear velocity = $\sqrt{Rig}$
κ = a universal constant characterizing turbulence
l = mixing length of momentum change
y = distance of the point from the wall
y_0 = a constant of integration

R = hydraulic radius
i = hydraulic gradient
g = acceleration due to gravity

This equation serves as the basis for the elementary mathematical development of this paper. Based on the hydrodynamical effects they produce, solid boundaries are usually classified as smooth, wavy, and rough. For smooth walls $y_0 = \dfrac{\nu}{9u_*}$ in which ν is the kinematic viscosity. For wavy walls $y_0 = f\left(\dfrac{k}{L}\right)\left(\dfrac{\nu}{u_*}\right)$ in which k is the height of the wave and L is its length; and for rough walls $y_0 = f\left(\dfrac{ku_*}{\nu}\right)\left(\dfrac{\nu}{u_*}\right)$ in which k is the elevation of the roughness elements. Experiments have shown that the resistance coefficient in pipes for a given Reynolds number is not affected by the shape of the pipe provided that in forming Reynolds number the hydraulic radius, R, is used as the characteristic length of the pipe. For smooth-walled pipes of circular cross-section the relation

$$\frac{\bar{u}}{\bar{u}_*} = 3.5 + 5.75 \log\left(\frac{R\bar{u}_*}{\nu}\right)$$

exists, and for flow between parallel walls of infinite extent,

$$\frac{\bar{u}}{\bar{u}_*} = 3.0 + 5.75 \log\left(\frac{R\bar{u}_*}{\nu}\right)$$

in which the bar indicates the average conditions in the channel. Where the roughness of the channel is equal to that caused by closely packed sand grains, for a circular pipe the relation

$$\frac{\bar{u}}{\bar{u}_*} = 6.5 + 5.75 \log\left(\frac{R}{k_s}\right)$$

exists, and for flow between parallel walls of infinite extent

$$\frac{\bar{u}}{\bar{u}_*} = 6.0 + 5.75 \log\left(\frac{R}{k_s}\right)$$

Similar relations are given also for polygonal channels and for channels of other shapes. These formulas are applied to Bazin's experimental data and to Manning's formula for rough channels. The analysis of Bazin's experiments on effect of roughness of channels, leads to the formula

$$\frac{\bar{u}}{\bar{u}_*} = 6.25 + 5.75 \log\left(\frac{R}{k_s}\right)$$

Values of k_s, the equivalent sand roughness, are given in the following table:

Type of surface	Cement	Brick	Fine gravel	Coarse gravel	Planks
k_s (cm.)...........	0.014	0.118	0.952	2.88	0.053

Formulas and tabulated data are stated in the article for wood surfaces as an example of waviness, the effect of the shape of cross section on the mean velocity, the distribution of velocity in rough channels, and the maximum velocity in rough rectangular channels. In a comparison of the standard formulas with Manning's formula it is found that the mean flow in rough channels is expressed as

$$\frac{\bar{u}}{\bar{u}_*} = 8.12 \left(\frac{R}{k_s}\right)^{1/6}$$

The formula holds for concrete, brick, and gravel when $\dfrac{k_s \bar{u}_*}{\nu} > 3.3$ and for planed wood when $\dfrac{k_s \bar{u}_*}{\nu} > 42.2$.—*H. E. Babbitt.*

Design of an Open-channel Control Section. KARL R. KENNISON. Proc. A.S.C.E. **65**: 763 (May '39). In designing an open channel to measure the flow of water the shape of the controlling section to produce any rating curve can be determined from the expressions:

$$d_c = \frac{mQ}{2} + mn \dots\dots\dots\dots\dots\dots (7)$$

$$B_c = \frac{1}{\sqrt{m^3 Q g}} \dots\dots\dots\dots\dots\dots (10)$$

$$d_p - d_c = QS \left(\frac{1}{2} - \frac{h_{vp} B_p}{A_p}\right) \dots\dots\dots\dots (18)$$

in which

A_p = cross-sectional area of channel at piezometer section.

B_c = width of the control section for depth.

B_p = surface width at piezometer section.

d_c = the distance from the bottom of the channel to any point in the control section.

d_p = the distance from the bottom of the channel to any point in the piezometer or normal channel section.

g = the acceleration of gravity.

h_f = $H_p - H_c$.

h_{vp} = the velocity-head at the piezometer, or normal, channel section.

H_c = the total energy, or depth plus velocity head, at the control section.

H_p = the total energy, or depth plus velocity head, at the piezometer or normal section of the channel.

$$m = \frac{Q + n}{H_p} = S + 2 h_{vp} \left(\frac{1}{Q} - \frac{B_p S}{A_p}\right) - \frac{\text{differential } h_f}{\text{differential } Q} \dots\dots\dots (14)$$

$$n = \frac{H_p}{m} - Q \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (15)$$

Q = rate of flow.

S = slope, or tangent to rating curve, at the piezometer section. The ordinates of the rating curve are d_p and its abscissas are Q.

In computing the dimensions of any control section the shapes of the piezometer, or normal, section and of the rating curve are first assumed. Then m is computed from (14); n from (15); d_c from (7) or (18) and B_c from (10). The shape of the control section is plotted from the computed values of d_c and B_c. It is to be noted that the Sutro weir is a special case of the general case presented in this paper.—*H. E. Babbitt.*

The Nomograph as an Aid in Computing Backwater Curves. I. H. STEINBERG. Civ. Eng. **9**: 365 (Jun. '39). In computing backwater curves by the rating curve, or Grimm method, it has been found that a nomograph can be constructed readily from the observed rating curves, which will eliminate the necessity of making several trial solutions in order to obtain the correct value of the open-river or natural discharge. A typical nomograph is shown in the article.—*H. E. Babbitt.*

Discharge of Submerged Sluice Gates. ROWLAND CUTHBERT ROBIN. J. Inst. Engrs. Australia **11**: 41 (Feb. '39). As result of a series of tests carried out on model gates in the hydraulic laboratory of the Univ. of Adelaide it has been found that:

$$Q = C'_D a \sqrt{2g\left(h + \frac{V_1^2}{2g}\right)} \quad\dots\dots\dots\dots\text{(IV)}$$

$$Q = C''_D a \sqrt{2gh} \quad\dots\dots\dots\dots\dots\dots\text{(V)}$$

$$\frac{d}{H_c} = \frac{d}{D_2 - R} \quad\dots\dots\dots\dots\dots\text{(VI)}$$

$$R = \frac{(2h')\dfrac{a}{A_2}}{\dfrac{1}{C} - \dfrac{a}{A_2}} = 2h' \frac{a}{A_2} C_D \quad\dots\dots\dots\dots\text{(VII)}$$

in which:

D_1 and D_2 = upstream and downstream depths above and below the gate, respectively.

H_c = depth of water in the vents, or passage between the training walls immediately downstream from the gate.

R = rise of water level downstream, i.e. $D_2 - H_c$.

A_1 = area of flow in the channel upstream from the regulator.

A_2 = area of flow in the channel downstream.

a = total area of the gate openings.

C = coefficient such that $C \times a$ = total of the effective areas of flow at the downstream end of the vents.

V_1 and V_2 = mean velocities of flow in the channels upstream and downstream, respectively.

V_c = mean velocity in the submerged and partially expanded jet at the downstream end of the vent.

h = difference between upstream and downstream levels.

h' = corrected head, i.e. $h + \dfrac{V_1^2}{2g} - \dfrac{V_2^2}{2g}$

d = height of gate opening.

b = width of a single vent.

n = number of open vents.

L = length of the vent downstream from gate.

B = surface width of downstream channel.

w = weight per cu. ft. of water.

Q = discharge in c.f.s.

C_D and C_D' = two forms of the coefficient of discharge.

$$C_D = 1 \div \left(\frac{1}{C} - \frac{a}{A_2} \right)$$

$$C_D' = 1 \div \sqrt{\left\{ \left(\frac{1}{C} - \frac{a}{A_2} \right)^2 + \left(\frac{a}{A_2} \right)^2 \right\}}$$

$$C_D'' = 1 \div \sqrt{\left\{ \left(\frac{1}{C} - \frac{a}{A_2} \right)^2 - \left(\frac{a}{A_1} \right)^2 + \left(\frac{a}{A_2} \right)^2 \right\}}$$

k = the smaller of 1.5 and $\left(0.6 + 0.4 \dfrac{B}{nb} \right)$; an empirical factor used to coordinate results from channels of different width.

In the solution of formula (VII) $1/C$ is unknown. In most cases it can be obtained closely enough to calculate R, either by using the known ratio d/D_2 or else an assumed value for d/H with which to enter the diagram given. With R calculated from expression (VII), a first approximation to d/H_c can be obtained from expression (VI). This first approximation will be found to be close enough in most cases, although a second approximation may be necessary in cases of large heads. Since the expressions are empirical the limits of the tests should be understood. (i) *Width.* The ratio of the surface width to total width of open vents must lie between 1.4 to 5.5. (ii) *Head.* The heads used ranged from about $\frac{1}{8}$ to 2.5 times the height of the opening. (iii) *Hydraulic Jump.* The method cannot be used where the hydraulic jump occurs. The jump will form when $1/C$ is about 1.5. The upper limit of the submerged range occurs when h is greater than $(1.5 - d/D_2) \left(\dfrac{D_2^2 - d^2}{4d} \right)$. (iv)

Entrance Conditions. The shape of the entrance appears to have very little influence on the rate of discharge. The ratio of height of opening to the upstream depth did, however, appear to have some influence.

The tests showed a wide range of consistency, calculated and observed discharges agreeing within 3%. Those few cases where larger discrepancies occurred, the largest being about 6%, were found under the following conditions: (i) With a very short vent (L/d = 1.3) and low submergences. (ii) With very long vents combined with low heads causing the jet to break up inside the vents. Extensive tabulation of test results included.—*H. E. Babbitt.*

Friction in Hydraulic Models. THOMAS DEF. ROGERS. Civ. Eng. **9**: 367 (Jun. '39). Hydraulic models are frequently built to investigate phenomena other than friction, for which, nevertheless, a knowledge of the effect of friction is essential. Common practice has been to use the Manning formula, in which the friction parameter, n, is supposedly a constant for any given surface. The inapplicability of this relationship is due to the fact that except for conditions of fully developed turbulence, n is not actually a constant but varies with the slope and the hydraulic radius. Furthermore it is known that the shape of the flow cross-section also influences its value. An investigation of the effect of roughness in open channels at the Univ. of Calif. indicates the manner of this variation and suggests another method of evaluating friction losses in models. By comparing the Blasius and Manning formulas the following expression for Manning's n for smooth surfaces may be derived

$$n = \frac{0.148 R^{1/24} \nu^{1/8}}{g V^{1/8}}$$

in which ν represents the kinematic viscosity and V the mean velocity. This applies only to hydraulically smooth surfaces. For rough surfaces n varies not only as the $\frac{1}{8}$th power of the roughness projections but also in some manner with the geometry of both the roughness and the flow cross-section. It may be concluded that unless the law governing this variation is known, geometric distortion of hydraulic models is advisable only for hydraulically smooth conduits if friction forces are of importance.—*H. E. Babbitt.*

Pressure Drop Accompanying Two-Component Flow Through Pipes. L. M. K. VOELTER AND ROBERT H. KEPNER. Ind. Eng. Chem. **31**: 426 (Apr. '39). In study of fuel-distributing systems for heaters in citrus orchards, pressure drops were measured for the flow of air-oil and air-water mixtures through $\frac{1}{4}''$ galv. iron, and through $\frac{1}{2}''$ and $\frac{3}{4}''$ black iron pipes, all placed horizontally. Within the pressure range studied, for a given air-oil ratio and a fixed air rate the pressure drop at any line pressure varies inversely as the air density. The pressure gradient for a single component varies inversely as the density at a given mass flow rate. It can be expressed as

$$\frac{\Delta p}{\Delta L} = -0.158 \frac{\mu^{1/4} G^{7/4}}{D^{5/4} g \rho}$$

in which p is lb./sq. ft. or sq. in.; L is length, ft.; μ is viscosity; G is mass rate per unit area, lb./(sec.)(sq. ft.); D, significant dimension, ft.; g is gravity; and ρ is density, lb./cu. ft. A system which will serve as the first idealization for two-component flow in the region studied may be visualized as a liquid flowing in the bottom of the pipe and the gas above it. The traction of the gas on the liquid surface will cause the liquid to flow. Preliminary computations on the power required to force a liquid through an inclined pipe (slope 1:6) result in the expression

$$\left(\frac{\Delta p}{\Delta L}\right) A_{\text{air}} = \tau_{\text{dry air-pipe}} \times (\text{air perimeter}) + \tau_{\text{air-oil}} \times (\text{chord length})$$

in which τ is traction, lb./sq. ft.; A is area, sq. ft.; and power per unit length required to lift the oil up the sloped pipe is

$$\frac{\text{power}}{\text{length}} = (\tau_{\text{air-oil}} V_{\text{air } c})_{\text{slope 1:6}} - (\tau_{\text{air-oil}} V_{\text{air } c})_{\text{horizontal}}$$

in which V = mean velocity, ft./sec., and c = chord length.—*H. E. Babbitt.*

Flow of Suspensions through Pipes. RICHARD H. WILHELM, DONALD M. WROUGHTON AND WILLIS F. LOEFFEL. Ind. Eng. Chem. **31**: 622 (May '39). Water suspensions (54 and 62% by wt.) of cement rock (92% passing No. 200 sieve) were pumped through 0.75″, 1.5″ and 3″ pipes at measured velocities of 0.19 to 11.4′ per sec. and pressure drop data recorded for 27′ lengths of pipe. Pressure drops calcd. for 100′ of pipe were 133 to 7240 lbs. per sq. ft. Flow was of 2 types, "plug" and turbulent. Separate correlation, using pipe and viscometer data, is presented for each type of flow. The variables friction factor and Reynolds number are used for turbulent flow; friction factor and velocity for "plug" flow. Similar data presented for Filter-Cel suspensions.— *Selma Gottlieb.*

Correlation of Rotameter Flow Rates. JOHN C. WHITWELL AND DAVID S. PLUMB. Ind. Eng. Chem. **31**: 451 (Apr. '39). The rotameter is a flow measuring device consisting of a vertical, graduated, tapered glass tube. The reading is the vertical distance from a zero point on the tube to a float in the tube. Position of the float is determined by the net effect of the buoyant and dynamic forces of the fluid flowing upward through the tube and around the float, and of gravity downward. For analysis the meter may be treated as an orifice of annular cross section; the size of the annulus varies with the position of the float. It is possible to calibrate the instrument with any desired fluid and through a method demonstrated in the article, to correlate the instrument with other fluids of varying physical characteristics. The correlation is applied only above certain critical values of Reynolds number; this fact, combined with experimental observations, indicates the induction of turbulence by irregularities of the float and by entrance conditions.—*H. E. Babbitt.*

Performance of Ejectors. LINCOLN T. WORK AND VINCENT W. HAEDRICH. Ind. Eng. Chem. **31**: 464 (Apr. '39). An ejector serves to permit the expansion of a pressure vapor through a nozzle across a zone of low pressure to a region of intermediate pressure. During the expansion the pressure vapor acquires considerable kinetic energy which may be put to useful work. Ejectors find wide applications in chemical industries, power stations, refrigeration, etc. In spite of the success of the ejector in practical application the process of entrainment remains one of the complex problems of fluid mechanics. At present design is generally empirical. For a given pressure drop across the jet the molal kinetic energy of the fluid should be essentially constant, regardless of fluid, because of the fact that the velocity will change in inverse ratio to the square root of the molecular weight, while the mass will be proportional to the

molecular weight. On the other hand the molal momentum of the jet fluid will change roughly in proportion to the square root of the molecular weight, and a large molecular weight will give more available momentum than a small one. Among the unanswered questions may be included whether a change in fluid will require a change in design; whether all fluids will behave alike; and how the different fluids will behave on the entraining side of the jet. The subject of entrainment has been divided into two classes: the specific case of entrainment in a single component system, i.e., self-entrainment, and the more general case in which different fluids are used in the boiler and in the evaporator, i.e. two-component entrainment. Based on the principle of the conservation of momentum it can be stated that $WV_1 = (W + w)V_2$ in which, W is the weight discharge of primary fluid in unit time, w is the weight of secondary fluid entrained in unit time, V_1 and V_2 are primary fluid velocities before and after impact, respectively. In self-entrainment it has been shown that the weight ratio of the primary to secondary fluid is a function of the pressure under conditions determined by a constant ratio of pressure differences, and all fluids in self-entrainment perform with equal effectiveness irrespective of molecular weights. In two-component entrainment, when one vapor is used to entrain another, the relations are more complex. When the characteristics of an ejector are known for operation with a single vapor, they may be determined for any other vapor or for a two-component system by the relations established in this study, which apply completely over the ranges of pressure, temperature, molecular weight, and molecular volume investigated. The variation of suction pressure with boiler and exhaust pressure is approx. the same for all vapors, irrespective of molecular weight when operating under conditions of no entrainment. In two-component entrainment, which includes self-entrainment as a special case, the amount of molal entrainment of any secondary fluid effected by any considerable primary fluid may be expressed by the equation: $\bar{w} = cM^N$ in which $\bar{w}$ is secondary fluid in lb. moles/hr.; c is a constant; M is the molecular weight of the secondary fluid; N is $-10^{-0.0064m}$; m is the molecular weight of the primary fluid.—*H. E. Babbitt.*

Hydraulic Engineering Research. H. WITTMANN. Deut. Wasserwirtschaft **34**: 246 (Jun. '39). So diverse are the functions of water in relation to man, whether as a chemical entity, as a route for traffic, or as a conveyor of energy, and so manifold are its aspects from the economical and the constructional standpoints, that almost every hydraulic engineering problem which arises demands individual treatment. The field of research embraces not alone hydrodynamics, but also the action of water upon the earth's crust, upon plants, and upon structures, and of these, in turn, upon water. The usual formulas, while suitable enough for many practical purposes, yet throw but little light upon mechanisms, the importance of which is being more clearly recognized every day. Examples are given, with illustrations, of hydraulic laboratory problems either solved, or under investigation.—*Frank Hannan.*

Hydraulic Calculations Involved in Planning of Barrages, Dams, etc., and Deductions Therefrom. A. SCHÄFER. Deut. Wasserwirtschaft **34**: 145, 209

(Apr., May '39).   Author deprecates the multiplicity of formulas and coefficients in general use and the divergencies encountered when it is sought to apply them to any particular problem.   He contends that insufficient weight has been assigned to energy relationships, upon which Rehbock has based his illuminative work in this field.   As exemplifying the simplification, precision, and flexibility attending the adoption of Rehbock's methods, five major problems, some from actual practice, are worked out in full.—*Frank Hannan*.